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44. *Division of the Pacific Area into Seven Regions in each of which Rayleigh Waves have the Same Group Velocities.*

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Abstract

Previousely[1], the south-western Pacific area was divided into four regions in each of which Rayleigh waves have the same group velocities. In the present paper, the same procedure applies for the whole Pacific area by adopting the dispersion data at many stations along abundant paths. Three regions denoted by "0", "A" and "B" are newly added. Special crustal conditions beneath the East Pacific Rise were confirmed.

1. Introduction

The Group velocity method, a method for estimating the crustal structure from the relation of group velocity$\sim$period of surface waves, gives us only information about the average crustal condition between a certain epicenter and an observational station. Therefore, when the travel length is so large as to cover the various crustal regions, the above-mentioned method is quite inadequate for ascertaining these regional crustal conditions.

Recently, the progress of ultra-long-period seismographs has attracted the attention of many seismologists to mantle surface waves. In this case, the long-period surface waves recorded by such instruments are not influenced by crustal irregularity, so that the group velocity method for long-period surface waves, classified as mantle surface waves, has become a new tool for obtaining valuable informations about the upper mantle situation.

The progress of electronic computers has, on the other hand, made it easier to compute the troublesome numerical calculation for the dispersion of higher mode surface waves of periods less than several seconds, and the estimation of crustal structure from the observation on such higher mode surface waves is now becoming a current problem.

Due to these circumstances given above, the group velocity method with medium-periods (25~60 seconds) looks like becoming outmoded. In spite of that, the writer found a new field of research in utilizing the group velocity dispersion data of the medium-period surface waves, that is, by using dispersion data along various paths for the discovery of different crustal regions in a vast area.

The first attempt was made in 1960[1] when it was found that dispersion characteristics of Rayleigh waves along many oceanic paths around Tsukuba Station, Japan could be classified into seven groups[2]. Characteristic numbers from "1" to "7", more continental in this order, were applied to each dispersion curve. The writer's attension was drawn

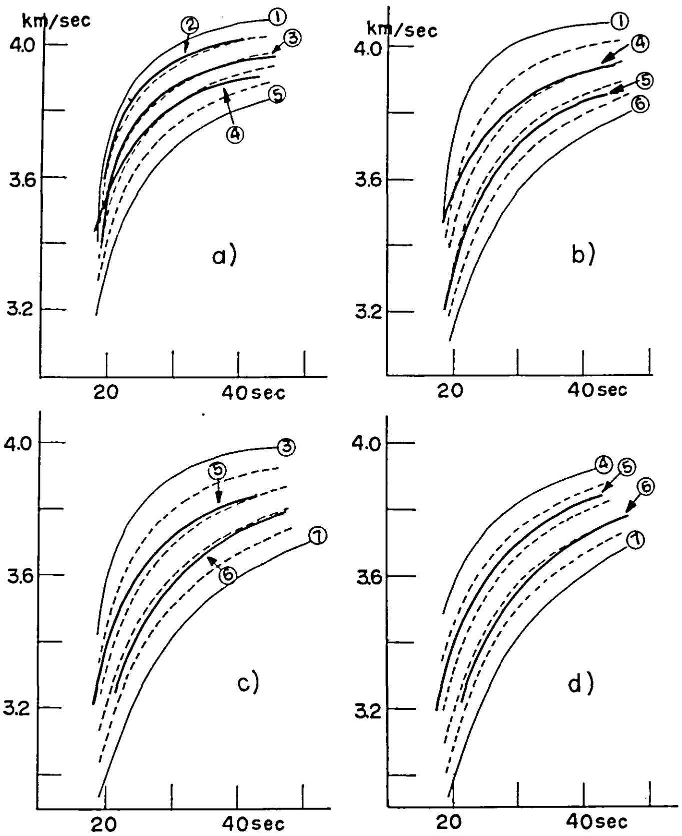

Fig. 1. Relation between classified dispersion curves.

to the fact that these classified dispersion curves from "1" to "7" were not independent of each other. Any one of the curves was found to be obtained by some suitable combinations of other curves. Such situations are as shown in Fig. 1. In Fig. 1–a), for instance, dashed curves between the two curves "1" and "5" indicate resultant ones when Rayleigh waves passed such regions as "1" (the region in which Rayleigh waves show the dispersion character "1") and "5" (the same meaning as above) with the path length ratios of 8 : 2, 6 : 4, 4 : 6 and 2 : 8 respectively from upper to lower in this order. Other classified curves "2", "3" and "4" well coincide with some of these dashed ones. Therefore, a classified curve, "3" for instance, can be resulted when Rayleigh waves have passed the two regions "1" and "5" with the pass length ratio of 6 : 4. Such conclusions can be made from any other diagrams in Fig. 1. The situation above mentioned provides a method for dividing the area in question into several regions so that all of the resultant dispersion characteristics along many traveling paths are well explained.

Division of the south-western Pacific Ocean in the western side of the Andesite line into four regions "1", "3", "5" and "7" was tried, the actual procedure being shown in schematic figure 2. In this figure, epicenters, observation stations, and traveling paths of Rayleigh waves are shown by full circles, circles with crosses and brocken lines respectively. Taking into account that the general tendency is for the crust to become thinner with increasing sea depth, contour lines of 4000 m, 3000 m and 1000 m were, as a first assumption, taken as preliminary boundaries of four regions "1", "3", "5" and "7" respectively.

On such preliminary divisions, the travel-times (C) of Rayleigh waves along a path was calculated by the formula

$$C=\Delta_1/V_1+\Delta_3/V_3+\Delta_5/V_5+\Delta_7/V_7$$

for certain periods. In this equation, V_1, V_3, V_5 and V_7 are the group velocities of Rayleigh waves which show the dispersion characters "1", "3", "5" and "7" respectively. The value of C thus found was compared to the observed travel-time (O) of Rayleigh waves along the path. Our purpose is to shift the preliminary boundaries so as to make the value of C as nearly as possible to the observed value O.

In order to obtain a unique solution, it is better, if possible, to begin with such a path, for instance, from the epicenter 1 to the station A in Fig. 2 which crosses only one contour line of 1000 m depth. In

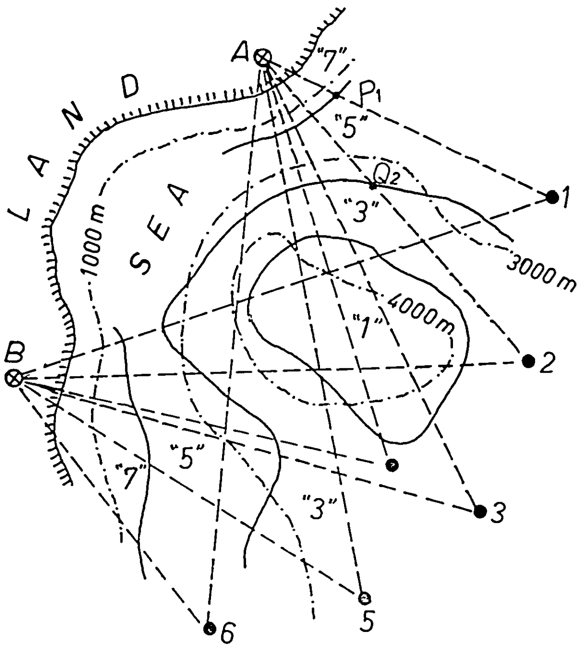

Fig. 2. Schematic figure which shows the method of dividing a certain area into four regions.

this case, the final suitable division point P_1 on this path can be uniquely decided. After that, the boundary line between "5" and "7" is drawn from the point P_1 approximately parallel to the 1000 m contour line. Then, on the next path, from 2 to A in Fig. 2, the shift of the preliminary boundaries can be achieved mainly for the boundary between "3" and "5". A point Q_2 is thus found.

Such procedures were successively made on every path. The division map thus completed from the dispersion data at a station A will become more reliable if we make the same procedures on other paths for another station B.

In this paper, a division map for the whole Pacific area thus obtained will be shown.

2. Materials

Group velocities of Rayleigh waves have already been observed by many seismologists along various paths in the Pacific Ocean. Among them, those which are limited to periods of less than 25 seconds are

Table I.

No.	λ (deg.)	φ (deg.)	Δ (km)	Authors	Station
1	46S	166E	1845	C. B. Officer[3]	Riverview
2	48S	164E	1910		
3	43.2S	169.3E	2260		Brisbane
4	25S	114W	7400		Christcharch
11 (5)	19N	146E	5880	J. E. Oliver, M. Ewing and F. Press[4]	Honolulu
12 (28)	18.5N	121E	8400		
13(42A)	24N	122E	8120		
14 (35)	33.3N	134.8E	6700		
15 (43)	47N	154E	5170		
16 (16)	43.5N	147E	5620		
17 (25)	60N	149W	4370		
18 (64)	14.5S	180E	4650		
19 (33a)	18.5S	170E	5640		
20 (17)	5.5S	151E	6320		
21 (23)	1S	78W	8990		
22 (2)	7.8S	77.8W	9300		
23 (27)	54S	71W	11700		
24 (21)	38S	72.5W	11050		
31 (56)	21.5N	120.5E	11270	T. Santô and M. Båth[5]	Pasadena
32 (46)	13.5N	121E	11930		
33 (08)	12.5N	125.5E	11670		
34 (54)	0.5S	132.5E	11800		
35 (51)	4.5S	135E	11830		
36 (19)	6S	147.8E	10720		
37 (36)	17.5S	167.5E	9720		
38 (13)	22S	169.5E	9830		
39 (60)	22S	174W	8590		
40 (03)	30S	177W	9440		
41 (35)	62S	153E	13260		
42 (63)	55S	152W	10430		
43 (34)	7S	80W	6050		
44 (47)	53.5S	131W	9800		
45 (57)	28.5S	113W	7000		
46 (31)	37S	98W	8200		
47 (53)	41.5S	74.5W	9520		
48 (32)	9S	109W	4890		
51 (46)	13.5N	121E	10200		Huancayo
52 (59)	4.5S	152.5E	14400		
53 (51)	4.5S	135E	16120		
54 (29)	41S	175.8E	10640		
55 (31)	37S	98W	3570		
61 (6)	25S	117W	6550	R. L. Kovach and F. Press[6]	Pasadena
62 (10)	21.5S	113W	4140		Huancayo
71 (124)	15S	75W	15750	T. Santô[7]	Tsukuba
72 (27)	21S	69W	16700		
73 (30)	33.5S	69.5W	17250		
74 (139)	27S	113W	13150		
75 (215)	42.4S	74.8W	16900		
76 (130)	38S	73W	17000		
77 (129)	45S	77W	16740		
78 (113)	57S	147.5W	12350		
79 (90)	63S	154E	11040		
81 (121)	7.5S	156E	5920	T. Santô[1]	Honolulu
82 (19)	12N	165E	4060		
83 (77)	7N	126.5E	8250		

(to be continued)

Table I. (continued)

No.	λ	φ	Δ	Authors	Station
91	6.8S	155.1E	5970	M. Ewing and F. Press[8]	
92	6.8S	155.1E	9810		Berkeley
93		〃	10220		Tuccson
94		〃	9850		Palisades
101 (P 1)	39.5N	143E	7360	J. Kuo, J. Brune and M. Major[9]	Suva
102 (P 2)	45.5N	151E	7570		
103 (P 3)	56N	162.5E	8090		
104 (P 4)	51N	173W	7670		
105 (P 5)	50.5N	175W	7630		
106 (P 6)	40N	126.6W	8590		
107 (P 7)	26.5N	111W	9075		
108 (P 8)	17.5N	97W	10050		
109 (P 9)	16.5S	71.5W	11460		
110 (P10)	27S	113W	7035		
111 (P11)	38S	73.5W	10280		
112 (P12)	58S	67W	9675		
113 (P13)	61.5S	154E	5190		
114 (P14)	7.4S	130.7E	5300		
121	11.4N	162.1E	3600	P. W. Pomeroy[10]	Tsukuba
122		〃	3800		Suva
123		〃	5200		Hongkong
124		〃	4400		Honolulu
125	11.4N	165.2E	4060		

excluded. Because the dispersion characteristics of Rayleigh waves in such a short-period range are more or less influenced by the sea depth along the path.

The data of shocks and the authors etc. are given in Table I. The shock numbers in bracket indicate those used in the original papers. In Fig. 3, some of the dispersion data obtained by other authors are shown. Velocity scales of these diagrams are all exaggerated about ten times the original values. Some classified curves are also given for comparison. All of the traveling paths of Rayleigh waves used are shown in Fig. 4.

For the purpose of making a preliminay division, a bathymetric chart in "Times Atlas of the world," London press 1958, was used. In Fig. 5, only a coutour line of 4000 m and the deep sea regions of more than 6000 m depth (marked by hatched region) are represented.

3. Assumed dispersion characters of Rayleigh waves through East Pacific Rise.

A dispersion character "0", the most oceanic type which has never been observed at Tsukuba Station, was newly found along the central

Pacific paths to Pasadena[5]. As a test to examine if this curve "0" could belong to the "1"~"7" series or not, group velocities of Rayleigh waves along the path which occupy two regions "0" and "4", "0" and "5", "0" and "6", "0" and "7", half and half in each segment, were calculated. The results are given in Fig. 6 by different marks, from which we can obtain a positive answer. For instance a curve "2" can be resulted if Rayleigh waves pass over two regions "0" and "4" by half and half. Similar conclusions can be made for other cases.

A problem was set, however, to divide the East Pacific Ocean. This was because, as previousely reported[5], Rayleigh waves which partly cover the East Pacific Rise showed new characteristics from "c" to "g" which

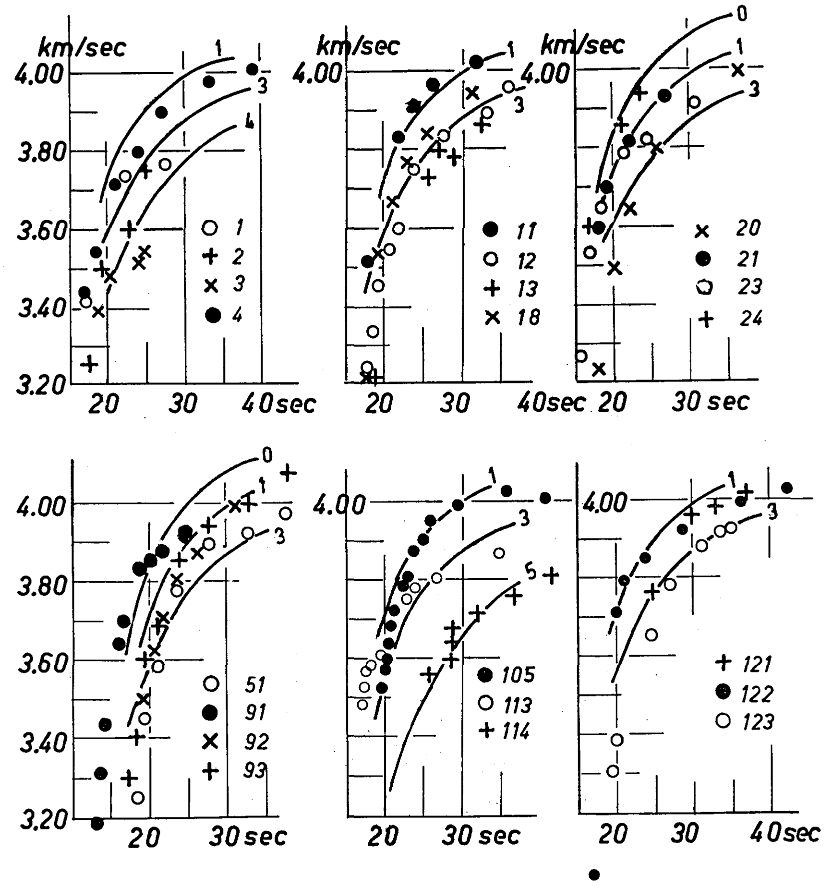

Fig. 3. Some examples of group velocity dispersion data of Rayleigh waves by other authors.

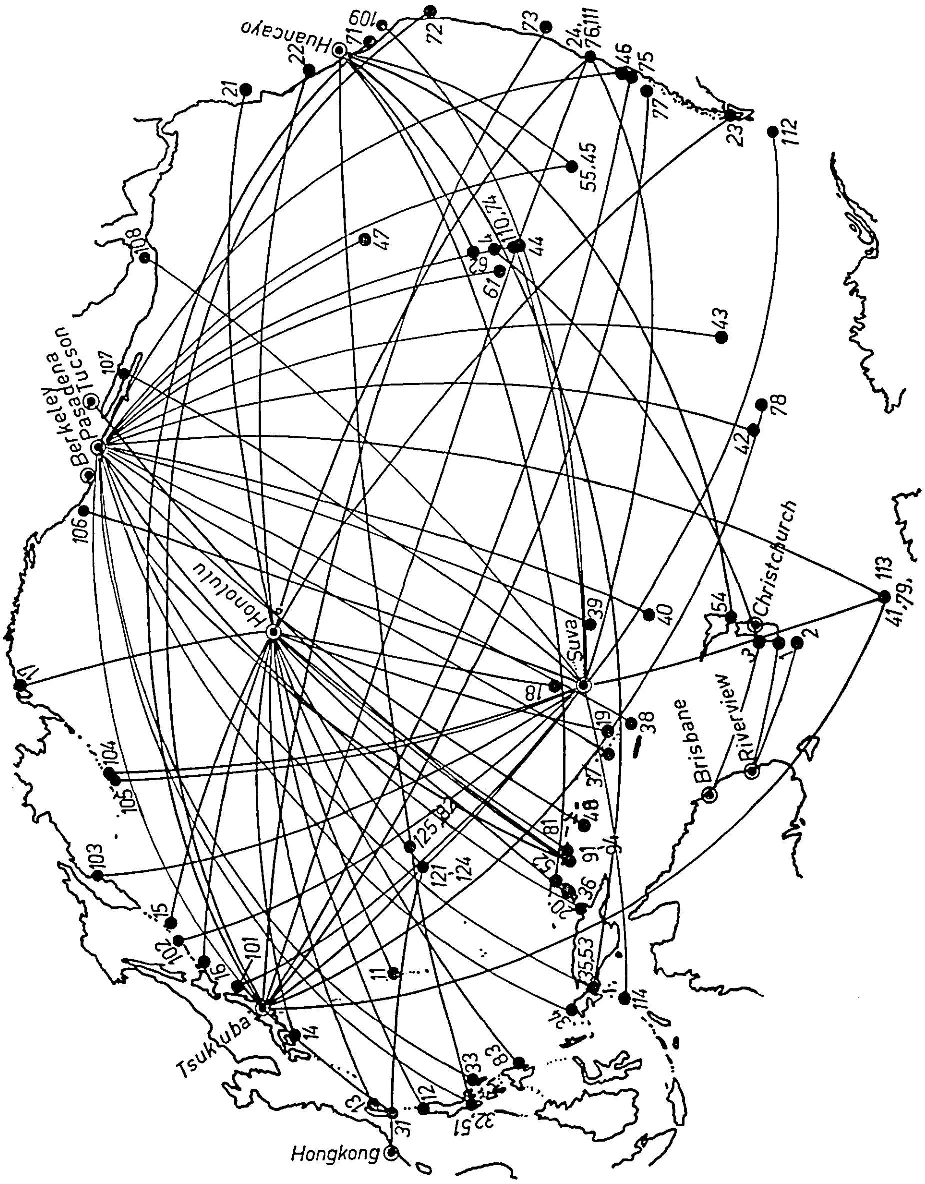

Fig. 4. Traveling paths of Rayleigh waves.

Fig. 5. Bathymetric chart of the Pacific Ocean

differs remarkably from the dispersion group "0" to "7". In such cases, some special dispersion characteristics for Rayleigh waves had to be assumed through the East Pacific Rise in order to make such special resultant dispersion characters possible.

As a preliminary, the East Pacific Rise region was divided from other regions by a 4000 m contour line. (Region A). Referring to the anomalous topographical and geophysical situations along the crest of the Rise, which have been observed by a few authors, a narrow band was suggested for along the crest. (Region B). The troublesome aspect was that we have to determine two dispersion curves "A" and "B", which Rayleigh waves might show in these regions "A" and "B" respectively, so as to explain the resultant dispersion data along many paths which crossed these anomalous regions in question.

After several trials, however, such dispersion characters and such shapes of regions "A" and "B" were decided and are as shown in Fig. 7 and Fig. 8 respectively.

4. Results and discussions

The final division map of the regions "0", "1", "3", "5", "7", "A" and "B" in the Pacific Ocean is shown in Fig. 8. Path length and travel-time in each region, calculated group velocities $V_c(=\sum_i \Delta_i/\sum_i t_i)$ and observed ones V_o of Rayleigh waves for three periods are given in Table II. Divisions were aimed to be made for resulting the ratios of $(O-C)/O$ less than 1%, from which we could get V_c to coincide with the observed value V_0 within the range of observational error. In Table II, we can see some cases when V_c differs more than ± 0.04 km/sec from V_0. These cases are, however, mostly limited to shorter periods. Therefore, these unsuccessful results might be more or less due to the influence of water layer along the paths.

From a comparative observation of the data in the two columns V_c and V_0 in Table II, we may deduce that our division map is quite satisfactory with the observed group velocities along the whole of the paths which crossed with each other in the Pacific Ocean.

The two suggested dispersion characters "A" and "B" along the East Pacific Rise must be discussed. In Fig. 7, these two curves are compared with other normal curves. Two specialities are well recognized from the figure, that is, 1) the maximum group velocity appears in a short period of about 25 seconds and 2) the maximum value of group

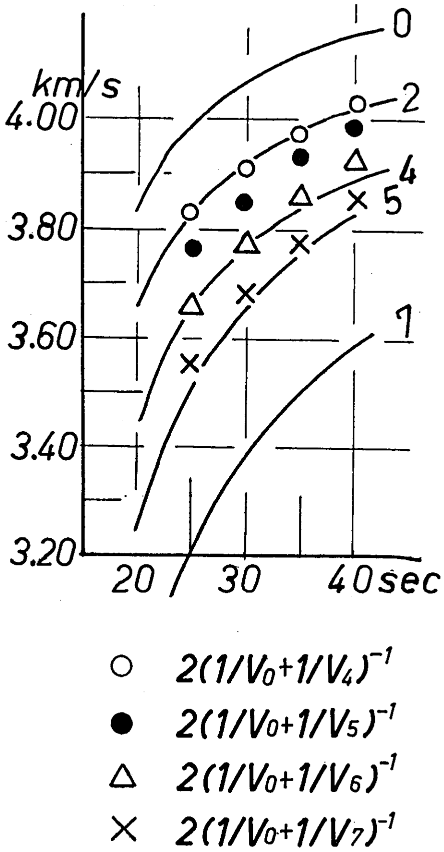

Fig. 6. Relation between a classified dispersion curve "0" and some other curves.

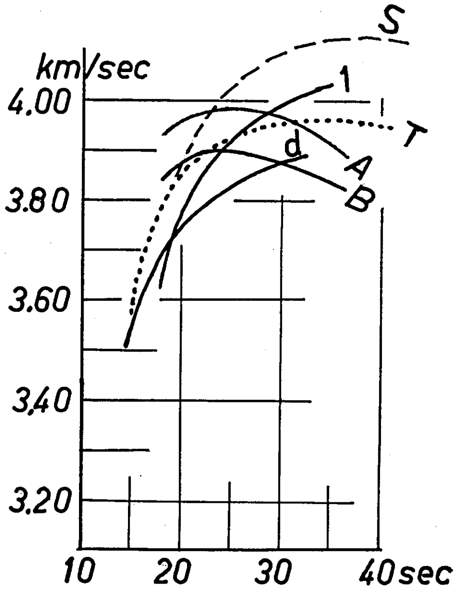

Fig. 7. Suggested group velocity dispersion curves "A" and "B" of Rayleigh waves. The following three curves are represented for comparison.

1: Classified curve denoted by the characteristic number "1".

T: Theoretical curve of the Case 1588 which was found by R. L. Kovach[6] as being the best one to fit the dispersion data of Rayleigh waves passing through the East Pacific Rise.

S: Standard oceanic dispersion curve of Rayleigh waves. (After J. Oliver[13].)

velocity in curve B is remarkably smaller than any other curve. Though the crustal structures which coincide with the curves "A" and "B" have not yet been found, we can estimate such a crustal structure with rather thin crust and with slow seismic velocity at the upper mantle from the general characters of these curves. Or, a low velocity layer may exist in the upper mantle quite near the Moho discontinuity. These suggestions given above coincide well with the result of the crustal profile across the East Pacific Rise given by H. W. Menard[11]. After Menard, the average crustal thickness within 1400 km of the crest in the East Pacific Rise is only 3.7 km, or 1 km less than that found at an average station elswhere in the Pacific basin. Further, the compressional velocity discovered at the upper mantle is only 7.5 km/sec, which is remarkably smaller than that of the ordinary basin. Characters of two dispersion curves "A" and "B" are both satisfactory ones with the refraction data given above.

The widths of the regions "A" and "B" can both be changed by varying the assumed dispersion curves "A" and "B". If we assume more abnormal curves, the widths of the regions will become narrower. After Menard, the width of the East Pacific Rise (which corresponds to the width of the region "A") and that of the highly abnormal belt (which corresponds to the region "B") are about 1400 km and 400 km respectively along a little northern section of Easter Island. In our results, they are about 2000 km and 500 km respectively across the same section. Therefore, our results are also satisfactory with regard to the widths of the regions.

In the division map, the region "B" branches off eastward following the 40°S line. This projection was made in order to explain the travel-time of Rayleigh waves along the path from Chile shock 75 to Tsukuba (see Fig. 4). It is also interesting that this branch just corresponds to that of the crest of oceanic ridge as is seen in Fig. 9.

5. Conclusions

The division map we obtained satisfies well with nearly all of the dispersion data of Rayleigh waves along various paths in the Pacific area. More detail and a more accurate regional crustal view must be left to the covering of refraction or gravitational measurements in the whole area. Considering, however, the practical difficulties of covering such measurements over such a vast area in a short time, map gives us the first gross crustal picture of the Pacific Ocean basin.

The results can be summarized as follows:

1) The western side of the Andesite line clearly shows continental crustal structure.

2) On the eastern side of the Andesite line, the Pacific basin of the thinnest crust with the dispersion character of "0" is divided into four by two bands which cross each other around Easter Island. The first band runs from southern Chile to the Marshall Islands region. The second one just corresponds to the East Pacific Rise.

3) Two abnormal dispersion curves "A" and "B" are suggested along the paths which occupy the East Pacific Rise. The general features of the crustal condition being suggested from these curves and

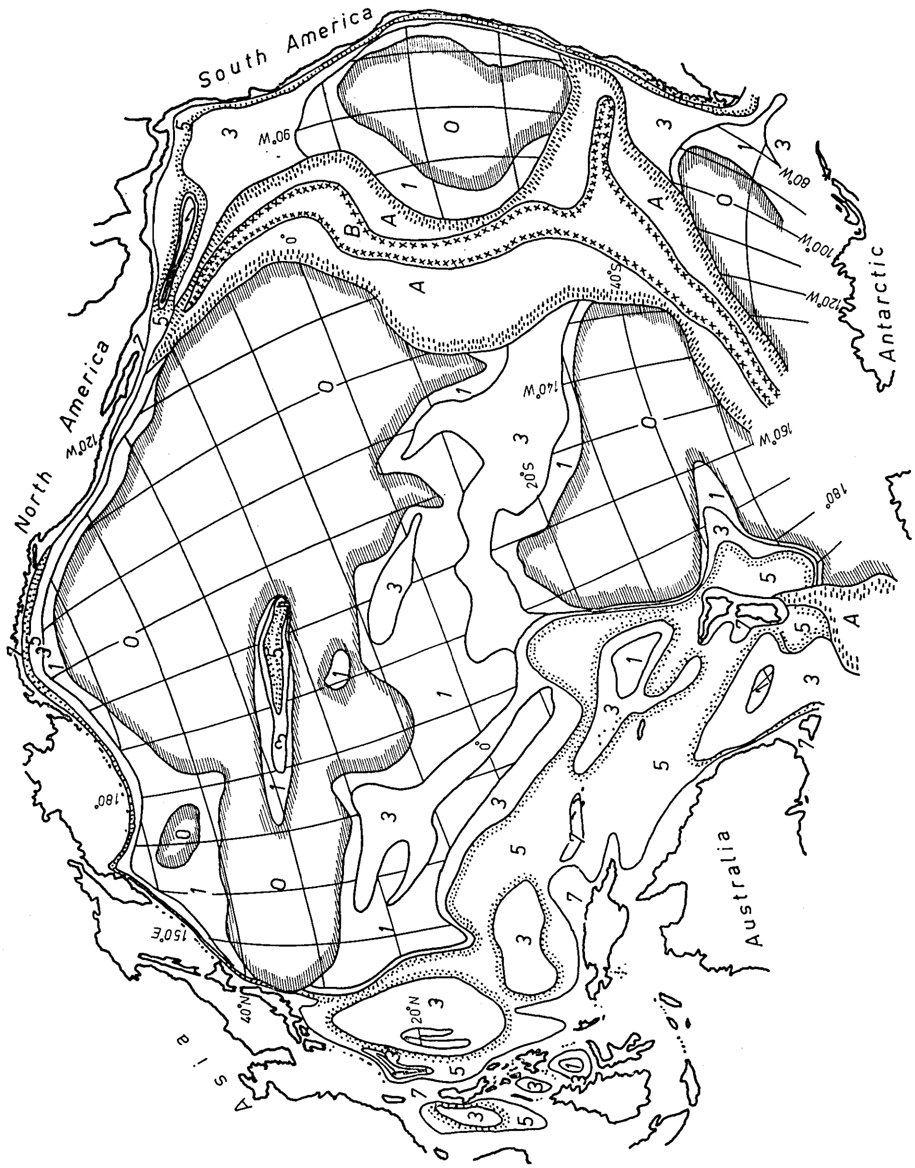

Fig. 8. Division map of the Pacific basin into seven regions.

the widths of the corresponding special crustal regions are both agreeable with the results from refraction data.

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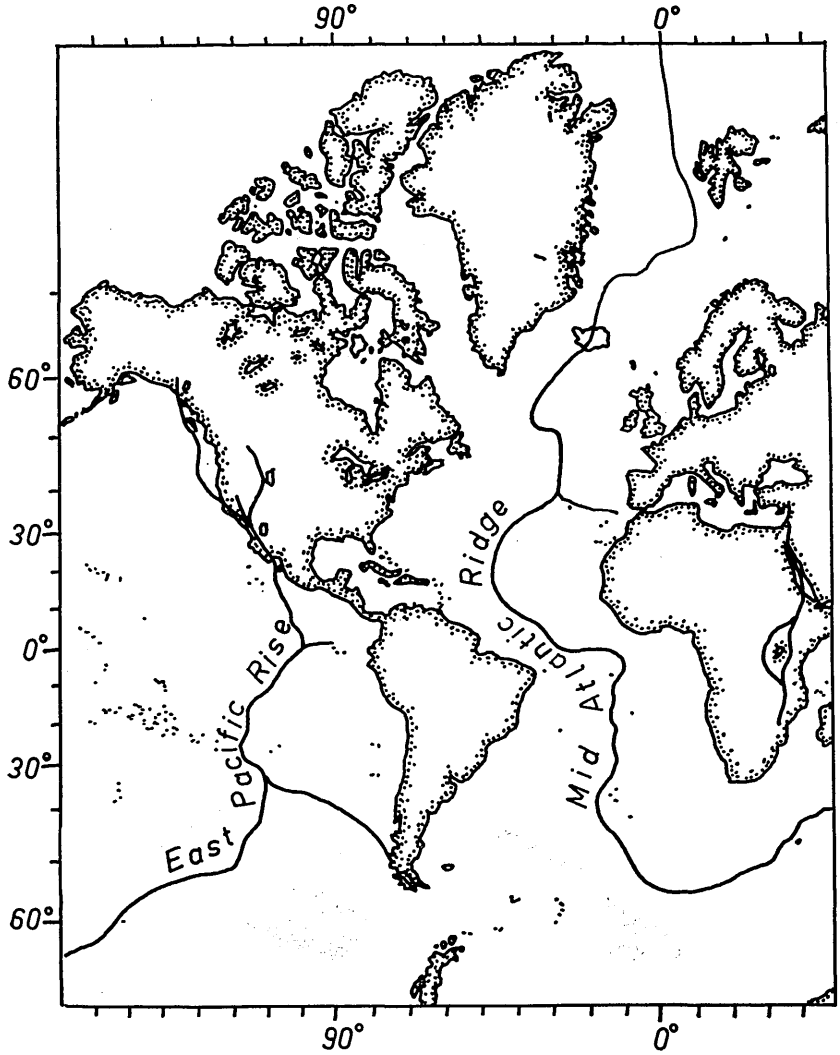

Fig. 9. Map of the mid-oceanic ridge in the East Pacific and Atlantic Oceans (After B. C. Heezen and M. Ewing[12]).

Table II.

Δ_i: Travel-lengths of Rayleigh waves in the region "i".
C : Calculated travel-times of Rayleigh waves over total path lengths.
O : Observed travel-times of Rayleigh waves over total path lengths.
t_i : Travel-times of Rayleigh waves in the region "i".
V_c: Calculated group velocity of Rayleigh waves.
V_o: Observed group velocity of Rayleigh waves.

No.	T (sec)	Δ_0 (km)	Δ_1 (km)	Δ_3 (km)	Δ_5 (km)	Δ_7 (km)	Δ_A (km)	Δ_B (km)	t_0 (sec)	t_1 (sec)	t_3 (sec)	t_5 (sec)	t_7 (sec)	t_A (sec)	t_B (sec)	C (sec)	O (sec)	O-C (sec)	(O-C)/O (%)	V_c (km/s)	V_o (km/s)
1	27.5	0	635	920	115	175	0	0	0	161	241	32	53	0	0	487	484	− 3	0.6	3.80	3.82
	25								0	163	244	33	55	0	0	495	491	− 4	0.8	3.74	3.76
	22.5								0	165	249	34	57	0	0	505	499	− 6	1.2	3.66	3.70
2	27.5	0	0	1145	595	170	0	0	0	0	300	165	52	0	0	517	516	− 1	0.2	3.70	3.70
	25								0	0	304	170	53	0	0	527	525	− 2	0.4	3.62	3.64
	22.5								0	0	310	175	55	0	0	540	541	+ 1	0.2	3.54	3.53
3	27.5	0	0	815	1110	335	0	0	0	0	214	308	101	0	0	623	630	+ 7	1.1	3.63	3.60
	25								0	0	216	318	105	0	0	639	639	0	0.0	3.55	3.55
	22.5								0	0	220	328	108	0	0	656	648	− 8	1.2	3.46	3.50
4	35	3220	700	1000	1050	130	1000	300	780	174	256	279	37	255	78	1859	1854	− 5	0.3	3.98	3.99
	30								790	175	259	287	38	252	78	1879	1875	− 4	0.2	3.94	3.95
	25								805	179	265	300	41	250	77	1917	1923	+ 6	0.3	3.86	3.85
11	33	3049	1435	1245	151	0	0	0	742	357	319	41	0	0	0	1459	1465	+ 6	0.4	4.02	4.02
	30								748	360	322	41	0	0	0	1471	1470	− 1	0.1	3.99	4.00
	27.5								754	363	326	42	0	0	0	1485	1477	− 8	0.5	3.96	3.98
12	35	2730	760	2660	1960	290	0	0	661	189	680	521	83	0	0	2134	2130	− 4	0.2	3.94	3.94
	30								670	191	690	535	86	0	0	2172	2176	+ 4	0.2	3.87	3.86
	25								682	195	705	560	91	0	0	2233	2235	+ 2	0.1	3.76	3.76
13	33	2630	940	1720	2200	630	0	0	640	234	441	590	183	0	0	2088	2100	+12	0.6	3.89	3.86
	30								645	236	446	601	188	0	0	2116	2125	+ 9	0.4	3.83	3.82
	25								657	240	456	629	197	0	0	2179	2146	−33	1.5	3.74	3.78
14	35	2995	1680	315	1050	660	0	0	725	417	80	280	189	0	0	1691	1675	−16	1.0	3.96	4.00
	30								734	420	82	287	196	0	0	1719	1710	− 9	0.5	3.90	3.92
	25								748	430	84	300	203	0	0	1765	1770	+ 5	0.3	3.79	3.79
15	27.5	1590	2400	470	710	0	0	0	394	608	123	197	0	0	0	1322	1331	+ 9	0.7	3.92	3.90
	25								398	615	125	203	0	0	0	1341	1360	+19	1.4	3.85	3.80
	22.5								404	625	127	209	0	0	0	1365	1398	+33	2.5	3.78	3.70
16	27.5	3430	1160	320	710	0	0	0	848	294	84	82	0	0	0	1420	1410	−10	0.7	3.96	3.98
	25								858	297	85	85	0	0	0	1443	1435	− 8	0.6	3.89	3.92
	22.5								870	302	87	89	0	0	0	1468	1470	+ 2	0.1	3.83	3.82
17	35	3115	500	250	310	195	0	0	758	124	64	146	56	0	0	1084	1081	− 3	0.3	4.03	4.04
	30								765	125	65	150	58	0	0	1098	1098	0	0.0	3.98	3.98
	25								782	128	66	157	61	0	0	1126	1128	+ 2	0.2	3.88	3.87

(to be continued)

Table II. (continued)

No.	T (sec)	Δ_0 (km)	Δ_1 (km)	Δ_3 (km)	Δ_5 (km)	Δ_7 (km)	Δ_A (km)	Δ_B (km)	t_0 (sec)	t_1 (sec)	t_3 (sec)	t_5 (sec)	t_7 (sec)	t_A (sec)	t_B (sec)	C (sec)	O (sec)	O-C (sec)	(O-C)/O (%)	V_c (km/s)	V_o (km/s)
18	35	1100	1750	1250	550	0	0	0	267	434	319	146	0	0	0	1166	1168	+ 2	0.2	3.99	3.98
	30								270	439	324	150	0	0	0	1183	1184	+ 1	0.1	3.93	3.93
	25								275	447	332	157	0	0	0	1211	1215	+ 4	0.3	3.84	3.83
19	30	1300	3530	660	150	0	0	0	319	885	171	41	0	0	0	1416	1423	+ 7	0.5	3.98	3.96
	27.5								321	895	173	42	0	0	0	1431	1438	+ 7	0.5	3.94	3.92
	25								325	903	175	43	0	0	0	1446	1455	+ 9	0.6	3.90	3.87
20	35	2500	1440	800	1280	300	0	0	605	358	204	343	86	0	0	1596	1581	−15	0.9	3.95	3.98
	30								613	361	207	350	89	0	0	1620	1617	− 3	0.2	3.91	3.91
	25								625	369	212	366	94	0	0	1666	1659	− 7	0.4	3.80	3.81
21	35	5450	0	1750	390	0	1400	0	1320	0	447	104	0	357	0	2228	2220	− 8	0.4	4.03	4.05
	30								1336	0	454	106	0	353	0	2249	2250	+ 1	0.0	3.99	3.99
	25								1362	0	465	111	0	351	0	2289	2290	+ 1	0.0	3.92	3.92
22	30	5780	0	1500	520	0	1500	0	1415	0	389	142	0	378	0	2324	2320	− 4	0.2	4.00	4.01
	27.5								1425	0	393	144	0	377	0	2339	2342	+ 3	0.1	3.98	3.97
	25								1445	0	398	148	0	376	0	2367	2365	− 2	0.1	3.93	3.93
23	35	3000	520	2700	700	0	3420	1360	727	129	690	186	0	873	355	2960	2960	0	0.0	3.95	3.95
	30								735	130	700	191	0	861	351	2968	3000	+32	1.1	3.94	3.91
	25								750	133	717	200	0	857	348	3005	3033	+28	0.9	3.91	3.87
24	25	7320	520	750	730	0	1100	630	1830	133	199	208	0	276	161	2807	2785	−22	0.8	3.94	3.97
	22.5								1860	135	202	214	0	277	161	2849	2830	−19	0.7	3.88	3.91
	20								1900	139	208	224	0	278	162	2916	2890	−21	0.7	3.80	3.82
31	30	5440	3100	210	1760	760	0	0	1330	777	54	480	226	0	0	2867	2860	− 7	0.2	3.93	3.94
	27.5								1342	785	55	488	230	0	0	2900	2890	−10	0.3	3.89	3.91
	25								1360	793	56	502	238	0	0	2949	2950	+ 1	0.0	3.82	3.82
32	33	6690	2420	1000	1160	660	0	0	1630	602	256	311	192	0	0	2991	3010	+19	0.6	3.94	3.96
	30								1640	607	259	317	196	0	0	3019	3030	+11	0.4	3.95	3.93
	27.5								1650	618	262	322	209	0	0	3061	3060	− 1	0.0	3.90	3.90
33	35	8070	1000	1430	780	390	0	0	1955	248	365	208	112	0	0	2888	2880	− 8	0.3	4.04	4.05
	30								1980	250	370	213	116	0	0	2929	2908	−21	0.7	3.98	4.01
	25								2018	256	380	223	122	0	0	2999	2978	−21	0.7	3.89	3.92
34	35	5600	1850	2400	1500	450	0	0	1363	459	613	399	129	0	0	2963	2930	−33	1.1	3.98	4.03
	30								1380	464	622	410	134	0	0	3010	2960	−50	1.7	3.92	3.99
	25								1405	473	637	429	140	0	0	3084	3020	−64	2.1	3.83	3.91

(to be continued)

Table II. (continued)

No.	T (sec)	Δ_0 (km)	Δ_1 (km)	Δ_3 (km)	Δ_5 (km)	Δ_7 (km)	Δ_A (km)	Δ_B (km)	t_0 (sec)	t_1 (sec)	t_3 (sec)	t_5 (sec)	t_7 (sec)	t_A (sec)	t_B (sec)	C (sec)	O (sec)	O-C (sec)	(O-C)/O (%)	V_c (km/s)	V_o (km/s)
35	35	5640	1800	2320	1250	820	0	0	1365	447	592	331	234	0	0	2969	2950	−19	0.6	3.98	4.01
	30								1380	452	602	342	244	0	0	3020	3000	−20	0.7	3.92	3.95
	25								1410	462	615	357	256	0	0	3098	3080	−18	0.6	3.82	3.84
36	35	5950	1420	840	1820	690	0	0	1440	352	214	484	197	0	0	2687	2700	+13	0.5	3.99	3.98
	30								1460	356	217	497	205	0	0	2735	2740	+ 5	0.2	3.91	3.92
	25								1488	364	223	520	216	0	0	2811	2800	−11	0.4	3.82	3.83
37	35	4900	2400	1550	680	190	0	0	1187	595	396	181	54	0	0	2413	2392	−21	0.9	4.03	4.06
	30								1200	601	401	186	56	0	0	2444	2429	−15	0.6	3.97	4.00
	25								1223	614	411	194	59	0	0	2501	2480	−21	0.8	3.88	3.92
38	35	4440	1500	2250	610	1030	0	0	1075	372	575	162	294	0	0	2478	2480	+ 2	0.1	3.96	3.96
	30								1085	377	583	168	307	0	0	2520	2520	0	0.0	3.90	3.90
	25								1110	384	597	174	322	0	0	2587	2550	−37	1.5	3.80	3.86
39	30	6200	950	1060	190	190	0	0	1520	238	275	52	57	0	0	2142	2130	−12	0.6	4.01	4.03
	27.5								1530	240	278	53	58	0	0	2159	2150	− 9	0.4	3.98	3.99
	25								1560	243	281	54	59	0	0	2197	2173	−24	1.1	3.91	3.96
40	35	7150	1360	550	190	190	0	0	1730	338	140	51	54	0	0	2313	2300	−13	0.6	4.08	4.11
	30								1750	341	142	52	56	0	0	2341	2330	−11	0.5	4.03	4.05
	25								1790	348	146	54	59	0	0	2397	2400	+ 3	0.1	3.94	3.93
41	30	8570	2320	1470	350	150	400	0	2100	582	381	93	43	101	0	3300	3280	−20	0.6	4.02	4.04
	27.5								2118	588	385	96	45	101	0	3333	3310	−18	0.5	3.99	4.01
	25								2240	594	390	100	47	101	0	3371	3350	−21	0.6	3.94	3.95
42	30	8510	410	1130	190	190	0	0	2080	103	293	52	57	0	0	2585	2575	−10	0.4	4.04	4.05
	27.5								2100	104	296	53	58	0	0	2611	2580	−31	1.2	4.00	4.04
	25								2130	105	300	54	59	0	0	2648	2615	−33	1.3	3.94	3.99
43	35	4100	400	1000	150	150	3100	900	997	100	255	40	43	791	234	2460	2470	+10	0.4	3.98	3.97
	30								1004	100	259	41	45	781	232	2462	2480	+18	0.7	3.98	3.95
	25								1024	102	265	43	47	777	231	2489	2510	+21	0.8	3.94	3.90
44	35	2800	0	0	730	200	840	2430	678	0	0	194	57	214	634	1777	1780	+ 3	0.2	3.93	3.93
	30								687	0	0	199	60	213	628	1787	1792	+ 5	0.3	3.92	3.91
	25								700	0	0	208	63	211	624	1806	1810	+ 4	0.2	3.87	3.87
45	35	2000	1300	0	850	200	3850	0	485	323	0	226	57	982	0	2073	2064	− 9	0.4	3.96	3.97
	30								490	326	0	232	60	970	0	2078	2070	− 8	0.4	3.96	3.96
	25								500	333	0	242	63	965	0	2103	2084	−19	0.9	3.91	3.94

(to be continued)

Table II. (continued)

No.	T (sec)	Δ_0 (km)	Δ_1 (km)	Δ_3 (km)	Δ_5 (km)	Δ_7 (km)	Δ_A (km)	Δ_B (km)	t_0 (sec)	t_1 (sec)	t_3 (sec)	t_5 (sec)	t_7 (sec)	t_A (sec)	t_B (sec)	C (sec)	O (sec)	O-C (sec)	(O-C)/O (%)	V_c (km/s)	V_o (km/s)
46	35	3100	0	0	620	2000	2000	1800	751	0	0	165	571	510	469	2466	2460	− 6	0.2	3.86	3.87
	30								760	0	0	169	596	505	465	2495	2510	+15	0.6	3.82	3.79
	25								775	0	0	177	625	501	462	2540	2530	−10	0.4	3.75	3.76
47	35	2620	0	0	650	250	1000	370	635	0	0	173	72	255	96	1231	1230	− 1	0.1	3.97	3.97
	30								642	0	0	177	75	252	96	1242	1238	− 4	0.3	3.94	3.95
	25								655	0	0	186	78	251	95	1265	1250	−15	1.2	3.87	3.91
48	30	5150	2200	1000	1350	300	0	0	1261	551	259	369	89	0	0	2529	2530	+ 1	0.0	3.95	3.95
	27.5								1273	558	262	375	91	0	0	2559	2540	−19	0.7	3.91	3.94
	25								1289	563	265	386	94	0	0	2597	2580	−17	0.7	3.86	3.88
51	35	4850	5250	3900	1300	500	1400	1000	1174	1304	995	346	143	357	261	4580	4600	+20	0.4	3.97	3.96
	30								1204	1316	1010	356	149	353	259	4647	4630	−17	0.4	3.92	3.93
	25								1213	1343	1034	371	156	351	256	4724	4720	− 4	0.1	3.85	3.86
52	30	2730	2000	3800	3100	230	1900	640	670	502	985	848	69	479	165	3718	3710	− 8	0.2	3.88	3.88
	25								683	512	1009	886	72	476	164	3802	3800	− 2	0.5	3.79	3.79
	22.5								695	520	1028	911	74	478	165	3871	3890	+19	0.5	3.72	3.71
53	30	5310	2100	1900	2480	2320	1400	610	1300	527	492	678	690	353	158	4198	4230	+32	0.8	3.82	3.81
	25								1327	538	504	720	725	351	158	4323	4310	−13	0.3	3.73	3.74
	22.5								1350	546	513	729	750	353	157	4398	4390	− 8	0.2	3.67	3.67
54	35	5100	1100	750	1040	200	1600	850	1234	273	192	277	57	408	221	2662	2690	+28	1.0	4.00	3.96
	30								1250	276	194	284	60	403	220	2687	2710	+23	0.8	3.96	3.93
	25								1275	282	199	297	63	401	218	2735	2760	+25	0.9	3.89	3.86
55	27.5	2340	750	0	280	200	0	0	578	190	0	80	63	0	0	911	909	− 2	0.2	3.93	3.93
	25								585	192	0	82	65	0	0	924	918	− 6	0.6	3.88	3.89
	22.5								593	195	0	86	68	0	0	942	928	−14	1.5	3.80	3.85
61	35	3380	0	0	850	200	2120	0	820	0	0	226	57	542	0	1645	1650	+ 5	0.3	3.97	3.96
	30								828	0	0	232	60	535	0	1655	1655	0	0.0	3.95	3.95
	25								845	0	0	243	63	530	0	1681	1673	− 8	0.5	3.88	3.91
62	25	2360	1000	0	230	200	350	0	590	256	0	66	63	88	0	1063	1060	− 3	0.3	3.89	3.90
	22.5								600	260	0	68	65	88	0	1081	1078	− 3	0.3	3.84	3.84
	20								614	268	0	71	68	88	0	1109	1103	− 6	0.5	3.74	3.75
71	35	8030	3000	2000	570	250	1900	0	1945	745	510	152	72	485	0	3909	3910	+ 1	0	4.04	4.04
	30								1965	752	519	156	75	476	0	3943	3960	+17	0.4	4.00	3.98
	25								2000	768	530	163	78	480	0	4019	4030	+11	0.3	3.93	3.91

(to be continued)

Table II. (continued)

No.	T (sec)	Δ_0 (km)	Δ_1 (km)	Δ_3 (km)	Δ_5 (km)	Δ_7 (km)	Δ_A (km)	Δ_B (km)	t_0 (sec)	t_1 (sec)	t_3 (sec)	t_5 (sec)	t_7 (sec)	t_A (sec)	t_B (sec)	C (sec)	O (sec)	O-C (sec)	(O-C)/O (%)	V_c (km/s)	V_o (km/s)
72	30	10000	3200	720	650	230	1900	0	2450	803	187	178	69	479	0	4166	4155	−11	0.3	4.01	4.02
	27.5								2470	810	188	180	70	478	0	4196	4204	− 8	0.2	3.98	3.97
	25								2500	820	191	186	72	477	0	4246	4240	− 6	0.1	3.93	3.94
73	35	11830	2500	900	200	420	700	700	2865	620	230	53	120	179	182	4249	4275	+26	0.6	4.07	4.04
	30								2900	627	233	55	125	177	181	4298	4320	+22	0.5	4.02	3.99
	25								2960	640	239	57	131	176	179	4382	4380	− 2	0.1	3.94	3.94
74	35	5370	2150	3000	100	300	1750	480	1300	534	765	27	86	447	125	3284	3290	+ 6	0.2	4.00	4.00
	30								1315	539	778	28	89	441	124	3314	3320	+ 6	0.2	3.97	3.96
	25								1341	550	797	29	94	439	123	3373	3400	+27	0.8	3.90	3.87
75	35	3000	2800	5600	300	250	1850	3100	727	695	1430	80	71	472	808	4283	4280	− 3	0.0	3.95	3.95
	30								760	702	1450	82	74	466	801	4308	4300	− 8	0.2	3.92	3.93
	25								775	716	1490	86	78	464	795	4375	4340	−35	0.8	3.87	3.90
76	35	6230	1450	3300	320	250	4400	1050	1508	360	843	85	72	1123	274	4265	4260	− 5	0.1	3.99	3.99
	30								1527	364	856	87	75	1110	272	4291	4300	+ 9	0.2	3.97	3.96
	25								1559	372	876	92	78	1102	270	4349	4360	+11	0.3	3.92	3.90
77	35	3300	6040	3750	200	250	1700	1500	800	1495	957	53	72	434	391	4202	4190	−12	0.3	3.99	4.00
	30								810	1513	873	54	75	428	388	4241	4215	−26	0.6	3.95	3.97
	25								825	1542	995	57	78	426	385	4308	4270	−38	0.9	3.89	3.92
78	35	2030	3820	2610	3260	300	130	200	491	948	665	857	86	33	52	3132	3130	− 2	0.1	3.93	3.95
	30								497	958	676	891	89	33	51	3195	3175	−20	0.6	3.87	3.89
	25								507	978	693	931	94	33	51	3287	3250	−37	1.1	3.76	3.80
79	35	0	1000	2100	1800	4740	1400	0	0	248	536	479	1352	358	0	2973	2980	+ 7	0.2	3.73	3.71
	30								0	250	545	492	1410	346	0	3043	3043	0	0.0	3.63	3.63
	25								0	256	557	515	1480	344	0	3152	3160	+ 8	0.3	3.51	3.50
81	35	2630	1150	1040	1100	0	0	0	637	286	265	293	0	0	0	1481	1490	+ 9	0.6	4.00	3.97
	30								645	288	270	300	0	0	0	1503	1510	+ 7	0.5	3.94	3.92
	25								658	294	276	314	0	0	0	1542	1540	− 2	0.1	3.84	3.84
82	35	2510	440	920	190	0	0	0	609	109	235	51	0	0	0	1004	1010	+ 6	0.6	4.04	4.02
	30								615	110	239	52	0	0	0	1016	1020	+ 4	0.4	4.00	3.98
	25								628	113	242	54	0	0	0	1037	1060	+23	2.3	3.92	3.83
83	35	2430	2280	2420	1120	0	0	0	589	566	617	300	0	0	0	2072	2070	− 2	0.1	3.98	3.98
	30								596	571	626	307	0	0	0	2100	2085	−15	0.7	3.91	3.95
	25								607	578	642	320	0	0	0	2152	2130	−22	1.0	3.83	3.87

(to be continued)

Table VII. (continued)

No.	T (sec)	Δ_0 (km)	Δ_1 (km)	Δ_3 (km)	Δ_5 (km)	Δ_7 (km)	Δ_A (km)	Δ_B (km)	t_0 (sec)	t_1 (sec)	t_3 (sec)	t_5 (sec)	t_7 (sec)	t_A (sec)	t_B (sec)	C (sec)	O (sec)	O-C (sec)	(O-C)/O (%)	V_c (km/s)	V_o (km/s)
91	35	2270	1550	950	1200	0	0	0	550	385	242	319	0	0	0	1496	1510	+14	0.9	3.99	3.96
	30								557	389	246	328	0	0	0	1520	1524	+ 4	0.3	3.92	3.91
	25								568	396	252	343	0	0	0	1559	1564	+ 5	0.3	3.83	3.81
92	30	5150	1850	1100	1300	450	0	0	1251	460	285	355	134	0	0	2485	2462	−23	0.9	3.94	3.96
	27.5								1261	468	288	361	136	0	0	2514	2517	+ 3	0.1	3.90	3.90
	25								1280	474	292	371	140	0	0	2557	2549	− 8	0.3	3.85	3.85
93	35	6110	1580	1050	1380	100	0	0	1480	392	268	367	29	0	0	2536	2532	− 4	0.2	4.04	4.04
	30								1500	396	272	377	30	0	0	2575	2570	− 5	0.2	3.98	3.98
	25								1527	404	279	394	31	0	0	2635	2621	−14	0.5	3.88	3.90
94	30	5120	2320	1010	1300	100	0	0	1254	582	262	356	30	0	0	2484	2487	+ 3	0.1	3.96	3.96
	27.5								1263	587	265	361	31	0	0	2507	2511	+ 4	0.2	3.92	3.92
	25								1280	594	268	372	32	0	0	2546	2552	+ 6	0.2	3.87	3.86
101	35	1800	3830	1300	280	150	0	0	436	951	332	75	43	0	0	1837	1840	+ 3	0.2	4.00	4.00
	30								441	960	337	76	45	0	0	1859	1850	− 9	0.5	3.96	3.98
	25								450	980	345	80	47	0	0	1902	1880	−22	1.2	3.85	3.91
102	35	2300	3200	1500	420	150	0	0	557	795	383	112	43	0	0	1890	1890	0	0.0	4.00	4.00
	30								564	803	389	114	45	0	0	1915	1900	−15	0.8	3.95	3.98
	25								575	819	392	120	47	0	0	1953	1930	−23	1.2	3.87	3.92
103	35	2500	3800	1070	420	300	0	0	605	943	273	112	86	0	0	2019	2012	− 7	0.3	4.02	4.02
	30								613	952	276	115	89	0	0	2045	2030	−15	0.7	3.95	3.98
	25								625	972	282	120	94	0	0	2093	2070	−23	1.1	3.86	3.90
104	35	3450	3100	800	170	150	0	0	836	770	204	45	43	0	0	1898	1905	+ 7	0.4	4.04	4.03
	30								845	777	207	46	45	0	0	1920	1914	− 6	0.3	3.99	4.01
	25								863	794	212	49	47	0	0	1965	1950	−15	0.8	3.90	3.93
105	35	3340	3170	800	170	150	0	0	810	787	204	45	43	0	0	1889	1893	+ 4	0.2	4.04	4.03
	30								819	795	207	46	45	0	0	1912	1905	− 7	0.4	3.99	4.00
	25								835	811	212	49	47	0	0	1954	1950	− 4	0.2	3.90	3.91
106	35	4330	1140	2200	770	150	0	0	1049	283	562	205	43	0	0	2142	2144	+ 2	0.9	4.01	4.00
	30								1060	286	570	210	45	0	0	2171	2161	−10	0.5	3.95	3.97
	25								1080	292	584	220	47	0	0	2223	2207	−16	0.7	3.86	3.89
107	35	4395	1000	1800	1140	400	340	0	1063	248	460	303	114	87	0	2275	2280	+ 5	0.2	3.99	3.98
	30								1076	253	467	312	119	86	0	2313	2280	−33	1.4	3.93	3.98
	25								1098	256	478	326	125	85	0	2368	2313	−55	2.4	3.83	3.93

(to be continued)

Table II. (continued)

No.	T (sec)	Δ_0 (km)	Δ_1 (km)	Δ_3 (km)	Δ_5 (km)	Δ_7 (km)	Δ_A (km)	Δ_B (km)	t_0 (sec)	t_1 (sec)	t_3 (sec)	t_5 (sec)	t_7 (sec)	t_A (sec)	t_B (sec)	C (sec)	O (sec)	O-C (sec)	(O-C)/O (%)	V_c (km/s)	V_o (km/s)
108	35	4600	2350	800	1450	200	650	0	1114	583	204	386	57	166	0	2510	2500	−10	0.4	4.01	4.02
	30								1127	589	207	396	59	164	0	2542	2520	−22	0.9	3.95	3.99
	25								1150	600	212	414	62	163	0	2601	2570	−31	1.2	3.87	3.92
109	35	3700	1510	3000	900	350	1400	600	896	375	765	239	100	357	156	2888	2870	−18	0.6	3.98	3.99
110	30	2050	885	1500	950	150	1250	250	503	222	389	260	45	315	65	1799	1770	−29	1.6	3.94	3.97
	27.5								507	224	393	264	46	314	64	1812	1778	−34	1.9	3.88	3.96
	25								513	226	398	271	47	314	64	1833	1790	−43	2.4	3.84	3.93
111	30	4660	600	0	870	150	2500	1500	1142	150	0	238	45	630	388	2593	2590	− 3	0.1	3.96	3.97
	27.5								1150	152	0	234	47	627	397	2607	2638	+31	1.2	3.92	3.90
	25								1165	154	0	228	46	630	401	2624	2610	−14	0.5	3.94	3.94
112	30	5510	1330	400	1035	150	820	430	1351	334	104	283	45	206	111	2434	2427	− 7	0.3	3.99	3.98
	27.5								1360	337	105	287	46	206	110	2451	2440	−11	0.5	3.95	3.97
	25								1380	340	106	296	47	206	110	2485	2470	−15	0.6	3.89	3.92
113	35	1000	790	400	1000	1000	1000	0	242	196	102	266	286	255	0	1347	1342	− 5	0.4	3.85	3.86
	30								245	198	104	273	298	252	0	1370	1350	−15	1.1	3.78	3.84
	25								250	202	106	286	312	251	0	1407	1376	−31	2.3	3.69	3.77
114	35	0	0	500	3880	920	0	0	0	0	127	1031	263	0	0	1421	1421	0	0.0	3.73	3.73
	30								0	0	129	1059	274	0	0	1462	1450	−12	0.8	3.62	3.65
	25								0	0	133	1107	287	0	0	1527	1510	−17	1.1	3.50	3.52
121	35	1200	800	1300	100	200	0	0	290	199	332	27	57	0	0	905	899	− 6	0.7	3.98	4.00
	30								294	200	337	28	60	0	0	919	912	− 7	0.8	3.92	3.95
	25								300	205	345	29	63	0	0	942	948	+ 6	0.6	3.82	3.80
122	35	0	2500	900	400	0	0	0	0	621	230	106	0	0	0	957	954	− 3	0.3	3.99	3.99
	30								0	627	233	109	0	0	0	969	962	− 7	0.7	3.92	3.95
	25								0	640	239	114	0	0	0	993	980	−13	1.3	3.83	3.88
123	35	800	1000	1550	1350	500	0	0	193	248	395	359	143	0	0	1338	1323	−15	1.1	3.88	3.93
	30								196	250	402	369	149	0	0	1366	1366	0	0.0	3.81	3.81
	25								200	256	411	385	156	0	0	1408	1410	+ 2	0.1	3.70	3.69
124	35	2300	600	1300	200	0	0	0	558	149	332	53	0	0	0	1092	1086	− 6	0.6	4.05	4.05
	30								563	150	337	55	0	0	0	1105	1100	− 5	0.5	3.98	4.00
	25								575	153	345	57	0	0	0	1130	1128	− 2	0.2	3.90	3.90
125	35	2510	440	920	190	0	0	0	608	109	234	51	0	0	0	1002	1002	0	0.0	4.04	4.05
	30								615	110	239	52	0	0	0	1016	1016	0	0.0	4.00	4.00
	25								628	113	242	54	0	0	0	1037	1041	+ 4	0.4	3.92	3.90

44. レーリー波の群速度にもとづいた太平洋底の分割

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前に西南太平洋海域について行なつたと同様の方法で，今度は全太平洋海域を，それぞれの領域中ではそれぞれレーリー波が各周期毎に同じ群速度を示すであろういくつかの領域に分けることを試みた．今まで太平洋海域で観測された多くの人達の資料中から，海水の厚さのえいきょうをあまりうけない25秒以上の周期をもつたレーリー波の群速度の値だけを用いた．

結果は第8図の通りである．この分割図にもとづいて各径路上で計算されたレーリー波の群速度のほとんどが，各周期毎にそれぞれ実際に観測されたそれらと観測誤差の範囲内で一致しているから，この分割図は，ほぼ太平洋底の地殻構造の場所的な相異を第一近似的には画いているといえるだろう．

この図を大観すると，

1) 南西部を走るいわゆる「安山岩線」の西側の部分はたしかに陸的な要素を帯びている．
2) 最も海洋的な地殻をもつていると思われる「0」という領域が，イースター島附近で交わる二本の帯で四分されている．そして，そのうちの南北に走る一本の帯は丁度東太平洋海嶺に当る．

などの事実がうかがえる．また，この海嶺下におけるレーリー波の分散性は，第9図の「A」「B」のような曲線が予想されるが，これらの曲線から想像されるこの海嶺下の地殻構造は，海の深さの割にはうすい地殻と，その上部で普通よりもおそい地震波速度をもつたマントルで構成されたもので，このことは，屈折法による結果とも一致する．あるいは，このあたりではマントル中の低速層が，モホのすぐ下まで顔を出しているのかも知れない．