BULLETIN OF THE EARTHQUAKE
RESEARCH INSTITUTE
Vol. 45 (1967), pp. 963-971

49. Lateral Variation of Rayleigh Wave Dispersion Character. Part IV: The Gulf of Mexico and Caribbean Sea.

By Tetsuo SANTÔ,

International Institute of Seismology and Earthquake Engineering.

(Read Sept. 12, 1967.—Received Sept. 27, 1967.)

Abstract

Regionalization of a certain area into several dispersion regions was performed for the Gulf of Mexico, Caribbean Sea and their surroundings. An interesting phenomenon was that a small area with such dispersion indexes of larger than *10* were revealed off the coast of Texas in the western part of the Gulf of Mexico. This result is well identified with the existence of a region having extremely thick sediments.

1. Introduction

As a continuation of a series of studies[1] on lateral variation of Rayleigh wave dispersion character in various areas, this paper reports the results of regionalization of the Gulf of Mexico and Caribbean Sea into several different dispersion regions.

In one of the previous studies[2], the region around Novaya Zemlya was found to have a dispersion index as large as *10* in spite of being covered by water. This peculiar evidence was well interpreted by the existence of an extremely thick sedimentary layer. In the same paper, it was also suggested that a similarly peculiar dispersion region was to be found in the western part of Gulf of Mexico. This suggestion was made from the dispersion data of Rayleigh waves obtained by D. H. Shurbet[3] and from the present author's additional data.

---

1) Summarized in:
T. SANTÔ and Y. SATÔ, "World-Wide Survey of the Regional Characteristics of Group Velocity Dispersion of Rayleigh Waves," *Bull. Earthq. Res. Inst.*, **44** (1966), 939.

2) T. SANTÔ, "Lateral Variation of Rayleigh Wave Dispersion Character. Part II: Eurasia," *Pure and Applied Geophysics*, **62** (1965), 67.

3) D. H. SHURBET, "The Effect of the Gulf of Mexico on Rayleigh Wave Dispersion," *J. Geophys. Res.*, **65** (1960), 1251.

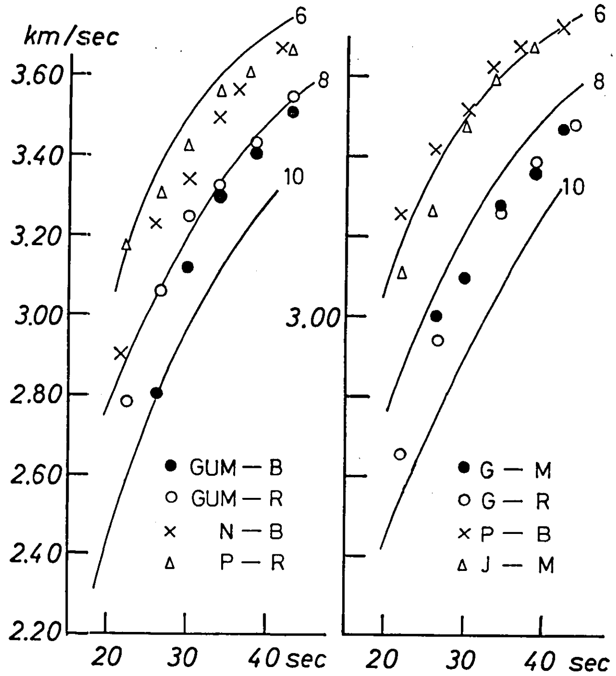

Fig. 1. Some examples of dispersion data of Rayleigh waves by B. C. Papazachos. Original data were replotted in the dispersion diagram in which the group velocity scale is highly exaggerated.

B. C. Papazachos[4] observed the dispersion of Rayleigh waves along a number of paths crossing the Gulf of Mexico and the Caribbean Sea. Some examples of his group velocity dispersion data are presented in Fig. 1 together with a few standard dispersion curves[5] *6*, *8* and *10* for comparison.

Remarkable difference can be seen between the two groups: one (open and filled circles) lies below curve *8* and another (triangles and crosses) lies on and near curve *6*. An important was the fact that the diminishing of group velocities in the first group comes from the situation that the path crosses a certain area in the western part of the Gulf of Mexico.

In Fig. 2, the paths along which Rayleigh wave travelled with

4) B. C. PAPAZACHOS, "Dispersion of Rayleigh Waves in the Gulf of Mexico and Caribbean Sea," *Bull. Seism. Soc. Amer.*, 54 (1964), 909.

5) *loc. cit.*, 2)

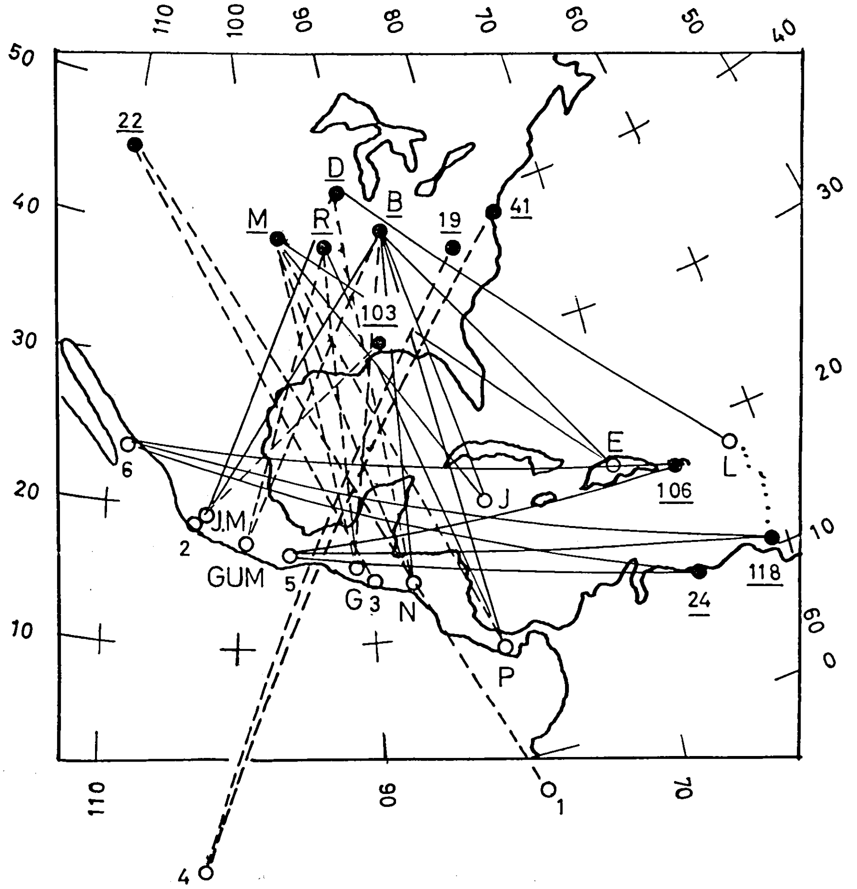

Fig. 2. Travelling paths of Rayleigh waves. Filled circles: Stations. Open circles: Epicenters. Dashed lines indicate the paths along which Rayleigh waves travelled with very slow group velocity.

remarkable low velocities are distinguished by dashed lines. It is quite clear that "something" exists in the north-western part of the Gulf, bordered by N-B, P-R and 6-106 paths. As fractions of the paths being occupied by this special area are mostly less than one-third of the total path lengths, it is safe to suggest that Rayleigh waves will show, in that part, such low group velocities as are expressed by the dispersion characteristic indexes of probably equal to or larger than *10*.

Papazachos estimated the thickness of the sedimentary layer in the western part of the Gulf of Mexico as 8 km in average from his group

Table 1. Data of Earthquakes.

a) Earthquakes used by B. C. Papazachos

	Date			Origin Time			Epicenter		d	M	Region
				h	m	s	λ	φ	km		
J. M.	Sept.	16	1962	03	05	33.0	19.3N	103.1W	100	5	Mexico
GUM	Mar.	27	1962	21	19	29.4	16.9N	99.9W	25		Mexico
G	Feb.	24	1963	13	34	15.9	14.6N	91.4W	135	5.7	Guatemala
N	Jan.	30	1962	08	34	26.8	12.7N	87.7W	101		Nicargar
P	Apr.	4	1962	14	02	30.2	8.0N	83.0W	23		Panama
J	July	25	1962	04	37	50.7	18.9N	81.1W	64		Jamaica
E	Jan.	8	1962	01	00	24.2	18.5N	70.5W	63	6.5	Espaniola
L	May	20	1962	15	01	20.7	20.5N	66.0W	38		Leeward

b) Earthquakes used by the present author

1	Mar.	20	1964	06	55	28.1	2.0S	79.7W	71	4.7	Ecuador
2	Mar.	21	1964	15	08	14.3	18.7N	103.1W	83	5.3	Michoacen, Mexico
3	Apr.	09	1964	04	15	23.0	13.5N	89.9W	89	5.0	El Salvador
4	May	28	1964	21	09	09.5	3.6S	102.7W	33	4.5	Galapagos Islands
5	Dec.	17	1964	13	59	25.3	16.0N	96.9W	36	4.9	Oaxaca, Mexico
6	Jan.	29	1965	00	11	22	23.9N	108.7W	33	5.4	Gulf of California

velocity as well as from phase velocity dispersion data. Several measurements and discussions have been made on the crustal structure in the Gulf of Mexico,[6),7),8)] and Papazachos' above conclusion was quite compatible with the results by other geophysical methods.

2. Materials

Group velocity dispersion data obtained by Papazachos cover a wide period range from 15 to 60 seconds. The paths are rather short in their

6) J. EWING, J. ANTOINE and M. EWING, "Geophysical Measurements in the Western Caribbean Sea and in the Gulf of Mexico," *J. Geophys. Res.*, **65** (1960), 4087.

7) J. I. EWING, J. L. WORZEL and M. EWING, "Sediments and Oceanic Structural History of the Gulf of Mexico," *J. Geophys. Res.*, **67** (1962), 2509.

8) J. ANTOINE and J. EWING, "Seismic Refraction Measurements of the Margins of the Gulf of Mexico," *J. Geophys. Res.*, **68** (1963), 1975.

Table 2. Travel-lengths Δ_i, travel-times t_i in every segment, and calculated group velocity of Rayleigh waves $V_C(=\Delta/\sum t_i)$ compared with observed one V_O. (Period: 30 seconds). O: Observed travel-time. a) On the paths used by B. C. Papazachos. b) On the paths used by the present author. The paths marked by * correspond to the dashed paths in Fig. 2 along which Rayleigh waves travelled with remarkably slow velocity.

(a)

Path	Segment [Travel-length (in km) Travel-time (in sec)]								Total length	O $\sum t_i$	V_O V_C	V_O-V_C
	1	*3*	*5*	*7*	*8*	*10*	*11*	*12*	Δ			
GUM−R*				1650 492	300 93	500 169			2450	754 752	3.25 3.26	−0.01
−B*				1600 475	300 93	300 101	200 72	300 112	2700	855 853	3.16 3.17	−0.01
J.M.−D*				2200 655	600 185				2800	843 840	3.32 3.33	−0.01
−B*				2100 625	600 185				2700	837 810	3.25 3.33	−0.08×
G−M*				2000 595		200 67	200 72	300 112	2700	844 845	3.20 3.20	+0.00
−R*				1900 565		200 67	200 72	300 112	2600	818 816	3.18 3.19	−0.01
−B*				2150 638		200 67	400 142		2750	856 847	3.21 3.25	−0.04×
N−M*				2550 758		100 34	200 72	300 112	3150	977 976	3.23 3.23	−0.00
−D*				3150 937		200 67			3350	1000 1004	3.35 3.34	+0.01
−B				2850 848					2850	848 848	3.36 3.36	0.00
P−M*			400 109	2950 877			100 36	200 75	3650	1090 1097	3.34 3.36	−0.02
−R		200 52	300 82	2950 877					3450	1005 1011	3.44 3.41	+0.03
−B		700 181	400 109	2300 684					3400	970 974	3.50 3.49	+0.01
J−M		400 104	300 82	2000 596					2700	778 782	3.47 3.45	+0.02
−B			300 82	2000 596					2300	677 678	3.40 3.40	+0.00
E−M		200 52	500 137	2650 789					3350	980 978	3.42 3.42	−0.00
−B		800 208	800 218	1200 357					2800	791 783	3.53 3.59	+0.06×
L−D	600 150	700 181	450 123	1700 505					3450	962 959	3.59 3.60	−0.01

Table 2. (b)

Path	Segment [Travel-length (in km) / Travel-time (in second)] 1	3	5	7	8	9	10	11	12	A	B	Δ	O Σt_i	V_O V_C	$V_O - V_C$
4- 41*	500 125		300 82	2700 803			200 67	200 72		900 227	600 155	5400	1532 1531	3.53 3.53	−0.00
4- 19*	550 138		300 82	2200 653			200 67	300 107		900 227	600 155	5050	1427 1429	3.54 3.54	+0.00
1- 22*	500 125		300 82	2800 832	1300 400	300 98	300 101	300 107	300 112			6100	1855 1857	3.29 3.29	+0.00
3- 22*				1650 490	1500 464	400 131	500 167					4050	1260 1252	3.22 3.23	−0.01
2-103*				1000 297	400 124		200 67	150 53	250 83			2000	633 634	3.14 3.14	−0.00
5-106			300 82	2900 863								3200	950 945	3.37 3.39	−0.02
5- 24			700 191	2500 742								3200	941 933	3.40 3.43	−0.03
5-118			800 218	3000 893								3800	1116 1111	3.41 3.42	−0.01
6-106				4200 1250	200 62							4400	1310 1312	3.36 3.35	+0.01
6- 24		200 52	1400 383	2750 818	300 93							4650	1336 1346	3.48 3.46	+0.02
6-118		700 191	1700 465	2600 772	200 62							5200	1485 1490	3.50 3.49	+0.01

lengths and covered the Gulf of Mexico and Caribbean Sea quite well. These are quite convenient to make a detail study on the lateral variation of dispersion character in rather small areas. Dispersion data along eighteen representative paths were used for the present study. The data of the related earthquakes are presented in Table 1-a. Additional data obtained from six earthquakes (Table 1-b) measured on seismographs at six World-Wide Standardized Stations are also used.

3. Result and discussions

"Crossing-path technique"[9] was applied along the thirty paths (see Fig. 2) well crossing with each other. A new standard dispersion curve *11* was defined having the following group velocities: 2.25, 2.53, 2.80, 3.00 and 3.15 km/sec for periods of 20, 25, 30, 35, and 40 seconds

9) *loc. cit.*, 2), for instance.

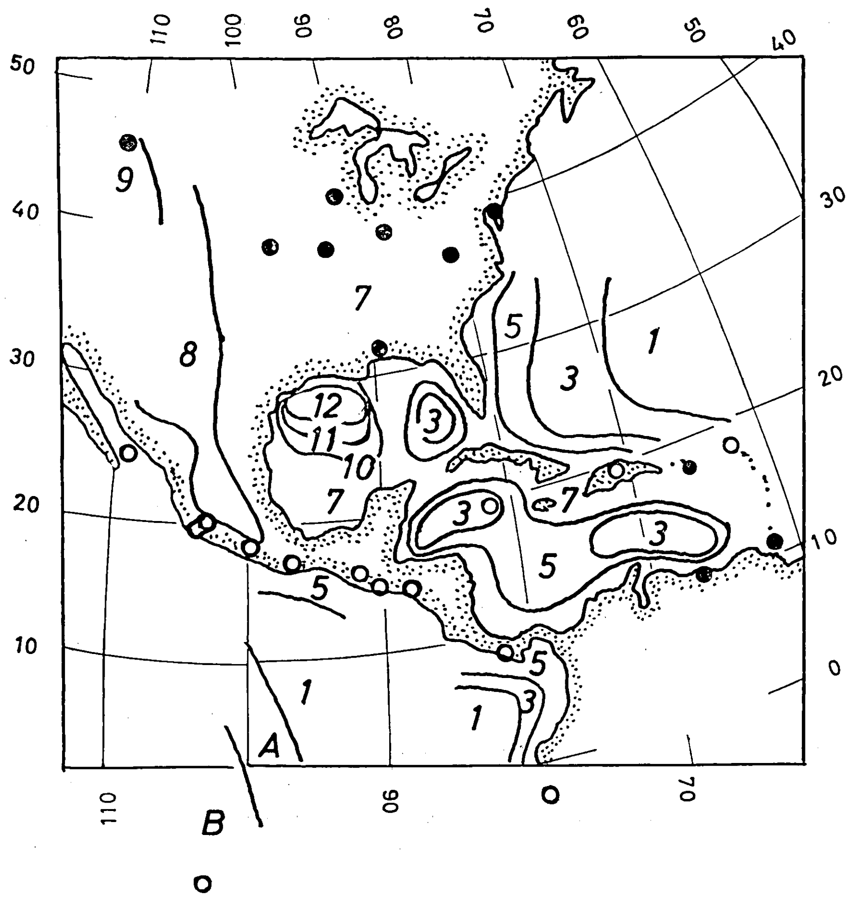

Fig. 3. Division pattern of dispersion regions. Positions of epicenters and stations are marked by open and filled circles respectively.

respectively.

Every path was successfully divided into such segments as are shown in Table 2. Except for a few unsatisfactory results (marked by $\times$) along the paths to station B, the calculated group velocity V_c (for the period of 30 seconds) are satisfactorily obtained with a difference of less than ± 0.03 km/sec to the observed values V_o.

By connecting the corresponding division points on every travelling path, a division pattern of several kinds of dispersion regions was obtained (Fig. 3). By the mutual relation between each standard dispersion curve, approximately the same division pattern must be drawn for Rayleigh waves with other periods (20-40 seconds).[10] Fig. 3, therefore, presents the lateral variation of Rayleigh wave dispersion character in the period range from 20 to 40 seconds at least. On this map, the division patterns previously found in the east Pacific Ocean[11] and in the west Atlantic Ocean[12] were partially used without any change.

Appearance of the oceanic dispersion region *3* in the eastern part of the Gulf of Mexico and in the Caribbean Sea, agreeing well with the bathymetric pattern, is considered quite reasonable. Appearance of the dispersion regions with such large dispersion indexes of ***10***, ***11*** and ***12*** off the coast of Texas, however, is quite exceptional. This evidence, however, is well identified with the existence of an extremely thick sediment suggested by refraction methods. The thickness of the sediment near the coast of Texas was actually estimated as 14 km.[13]

In the previous studies, the division of a certain area into different dispersion regions was usually made by utilising the dispersion data along the long travelling paths. This situation was always restricted by the distributions of both epicenters and the stations with long-period seismographs. In these cases small dispersion regions, say less than 300 km in diameter, if existing, were apt to be missed.

On this point, the area around the Gulf of Mexico and Caribbean Sea treated in the present paper had really an exceptionally favourable condition. Epicenters and suitable stations were well facing each other on both sides of the Gulf and the Sea with rather short distances between them. Any other place on the earth can hardly be found which has such a favourable condition.

Through the series of studies, many special areas have been revealed for which more detailed division patterns of dispersion regions were required to be delineated. It is also a fact that we have still many other areas over which the crustal speciality might be revealed by the "crossing-path technique". Permanent stations now distributed in the world, however, are not available for satisfying the above-mentioned requirments. Special observations should be made by setting some temporary stations

10) *loc. cit.*, 2), for instance.

11) T. SANTÔ, "Reconfirmation of the Existence of Special Dispersion Regions Along East Pacific Rise and Some Revisions on the Division Pattern of Dispersion Regions in the East and South Pacific Area," *Bull. Intern. Inst. Seism. Earthq. Eng.*, 4. (1967), in press.

12) T. SANTÔ, "Lateral Variation of Rayleigh Wave Dispersion Character. Part III: Atlantic Ocean, Africa and Indian Ocean," *Pure and Applied Geophysics*, 63 (1960), 40.

13) *loc. cit.*, 6), 8), for instance.

for a certain period, say one year. The positions of these stations must be carefully selected so that surface waves arriving at the stations will cross the area in question in many directions with different profiles.

---

49. レイリー波群速度分散性の地理的分布 IV: —メキシコ湾とカリブ海—

国際地震・地震工学研修所 三 東 哲 夫

メキシコ湾，カリブ海およびそれらの周辺を通る多くの径路にそってのレイリー波の分散性が，B. C. Papazachos によって調べられている．本篇は，これらの資料を主に用いて，メキシコ湾周辺の海域をいくつかの分散区に分けた結果の報告である．従来の場合とちがって，径路が比較的短いので，わりにこまかい分散区の区分も出来た．

メキシコ湾内のどこかに，レイリー波の速度をたいへんにおそくする地殻構造をもった部分があることは前から想像されていたが，こんどの研究で，その場所が湾の西半分のさらに北半分であることがはっきりした．最も群速度のおそい分散区の番号は「12」である．そしてこの場所は，地震の屈折波を用いる方法その他によって，10 数 km もの厚い堆積層が見つかっている場所とほゞ一致している．