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LATERAL VARIATION OF SURFACE-WAVE ANELASTIC ATTENUATION ACROSS THE PACIFIC

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ABSTRACT

Seismograms from island stations within or near the edge of the Pacific plate were used to obtain surface-wave attenuation coefficients in the period range 18 to 110 sec for Rayleigh waves and 20 to 110 sec for Love waves. The average Rayleigh-wave attenuation coefficient values range from a maximum of 1.64 × 10^{-4} km^{-1} at short periods to a minimum of 0.72 × 10^{-4} km^{-1} at longer periods. Corresponding extreme values for Love waves are 3.30 × 10^{-4} km^{-1} and 0.60 × 10^{-4} km^{-1}. The data are characterized by relatively large standard deviations which reflect departures from an ideal medium having laterally homogeneous elastic and anelastic properties.

The possibility of regional variations in anelastic properties was examined by dividing the Pacific into three regions according to age (0 to 50 m.y., 50 to 100 m.y., >100 m.y.). A systematic decrease in attenuation coefficient values over most of the period range is readily apparent from the data. Q_β^{-1} models obtained by stochastic inversion of the attenuation data suggest that the observed differences are produced by increasing values of Q_β in the low Q zone (at depths of 40 to 200 km), and possibly also by increasing values of Q_β in the lithosphere, as the age of the Pacific sea floor increases.

Introduction

Seismic surface-wave velocities have provided important information on the elastic properties of the Pacific plate and of the material beneath it. Multi-layered velocity models for a broad region of the Pacific have been obtained by Dorman *et al.* (1960), Saito and Takeuchi (1966), and Piermattei and Nowroozi (1969). More recent work (Kausel *et al.* 1974; Forsyth, 1975; Yoshii, 1975; Schlue and Knopoff, 1977; Yu and Mitchell, 1978) has indicated a systematic relationship between surface-wave velocities and the age of the lithosphere in the Pacific. The observed surface-wave velocities in all of those studies increase with increasing age of the lithosphere. A major factor contributing to the velocity variation, as shown by all of the above studies, is an increase in thickness of the lithosphere and a corresponding decrease in thickness of the asthenosphere. Yu and Mitchell (1978) have also shown that velocities in the lithosphere and in the upper portion of the low-velocity zone also increase systematically with the age of the Pacific sea floor.

Far fewer studies of the attenuation of seismic surface waves across the Pacific have been completed. Tsai and Aki (1969) obtained attenuation coefficient values at periods between 15 and 50 sec for a single path across the Pacific. Mitchell *et al.* (1976) obtained average attenuation coefficient values at periods between 15 and 110 sec for Rayleigh and Love waves over a broad portion of the Pacific. Other studies of surface-wave attenuation across oceanic regions have been done for the Atlantic or for mixed paths across oceans and continents (e.g., Ben-Menahem, 1965; Kanamori, 1970).

Mitchell *et al.* (1977) attempted to investigate regional variations of anelastic properties beneath the Pacific. They compared attenuation coefficients obtained for the eastern Pacific to average values for a broad region of the Pacific which were

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obtained by Mitchell *et al.* (1976). Although much scatter was present in their data, the attenuation coefficients were higher than average Pacific values, especially for a path along the east Pacific rise.

The present study is an attempt to detect systematic changes in anelastic properties across a broader region of the Pacific. In order to do so, we must use a different method than that employed by Mitchell *et al.* (1976, 1977). Those authors employed the method of Tsai and Aki (1969) which fits observed spectral amplitudes to those expected theoretically for an earthquake with a known fault-plane solution.

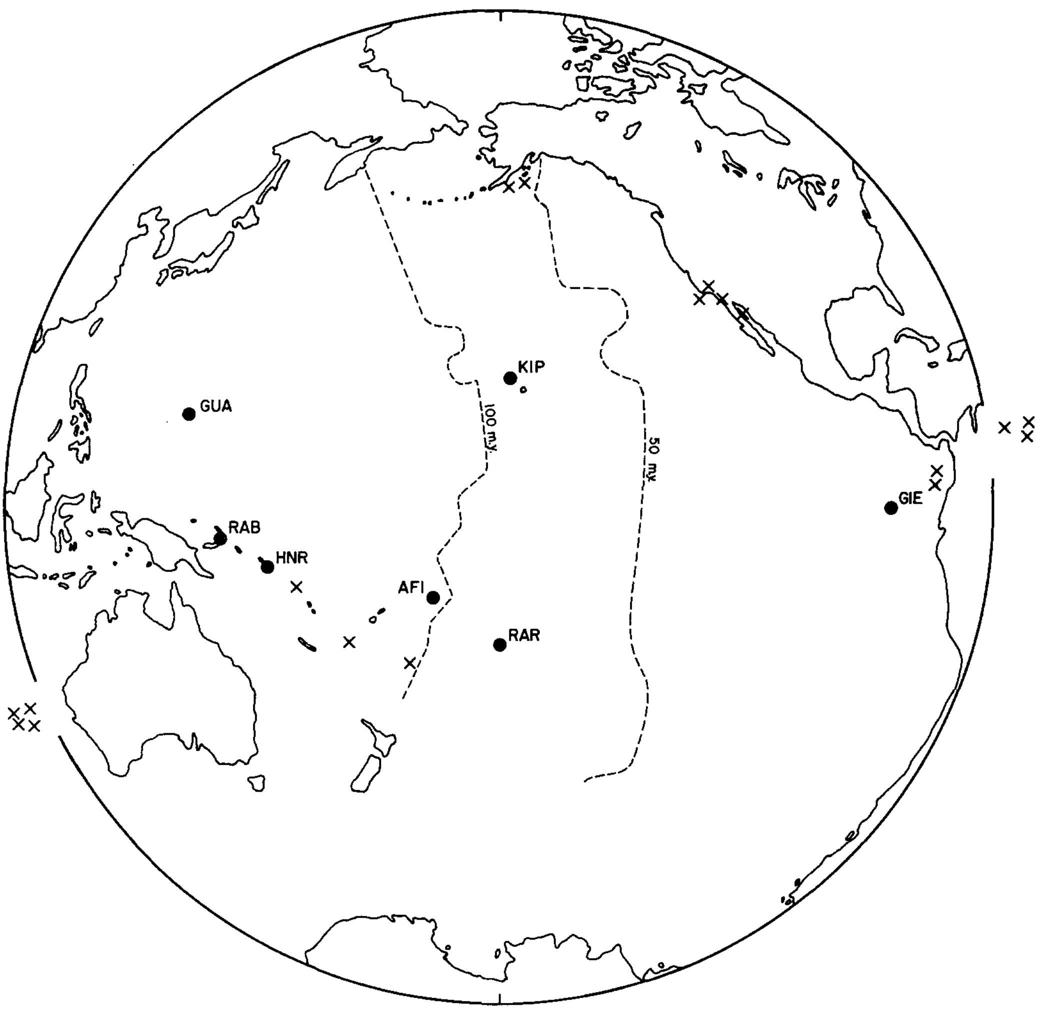

FIG. 1. Map of the Pacific, including stations and events used, and isochrons of 0, 50, and 100 million year ages.

That method requires many stations over a broad region and attempts to find average attenuation coefficient values for that region. If regional variations in anelastic properties occur over that region, however, it is possible that the obtained attenuation coefficient values can be biased either too high or too low and will not represent average values (Mitchell, 1975; Yacoub and Mitchell, 1977).

The method we will employ in the present study requires only two stations which are in line with selected seismic events. Using this method will allow us to look at more restricted portions of the Pacific in an attempt to observe regional variations in anelasticity.

DATA

Fundamental mode Rayleigh- and Love-wave attenuation coefficients have been obtained using 16 events for Rayleigh waves and 7 events for Love waves (Figure 1 and Table 1). Observations of surface waves from those events were made using 7 seismograph stations, all of which are part of the World Wide Standard Seismograph Network (WWSSN). All of the events were selected such that they lie along a great circle path between two of the stations.

Attenuation coefficient determinations require the observation of surface-wave amplitudes. It is well-known that amplitude data are characterized by much greater

TABLE 1

EARTHQUAKES AND STATIONS USED FOR ATTENUATION COEFFICIENT DETERMINATIONS

Date	Epicenter		Origin Time	Stations Used for Rayleigh Waves	Stations Used for Love Waves
	Latitude	Longitude			
18 Nov 63	29.9N	113.6W	14:38:28.9	KIP-RAB	
23 Oct 64	19.8N	56.0W	1:56:03.2	KIP-RAB	
20 Aug 65	22.8S	176.2W	21:21:51.5	RAR-GIE	
22 Dec 65	58.4N	153.1W	19:41:23.1	KIP-RAR	
7 Aug 66	31.8N	114.5W	17:36:26.7	KIP-RAB	
15 Jun 68	5.6N	82.6W	7:08:48.1	KIP-GUA	KIP-GUA
10 Jul 68	36.8S	78.5E	11:16:44.6	HNR-KIP	
20 Sep 68	10.7N	62.7W	6:00:03.5	GIE-RAR	GIE-RAR
22 Oct 69	34.6N	121.6W	22:51:29.0	KIP-HNR	
11 Mar 70	57.5N	153.9W	22:38:34.6	KIP-RAR	
9 Feb 71	34.4N	118.4W	14:00:41.8	KIP-HNR	
12 Aug 72	5.0N	82.6W	13:15:48.1	KIP-GUA	
5 Sep 72	19.9S	169.0E	17:30:35.6	RAR-GIE	RAR-GIE
6 Jan 73	14.7S	166.4E	15:52:41.9	AFI-GIE	
25 Jun 74	26.1S	84.3E	17:22:19.3		RAB-KIP
27 Sep 74	2.7N	71.4W	4:09:01.3	GIE-AFI	GIE-AFI
14 Jul 75	40.4S	78.4E	23:27:55.0	HNR-KIP	HNR-KIP
19 Sep 75	34.8S	81.8E	3:37:11.7		HNR-KIP

uncertainty than velocity data. We have tried to minimize the scatter in our amplitude data in three ways. First, we have restricted departures from an exact great circle path between stations to be less than three azimuthal degrees. Second, we have used only those stations which are situated on small islands within, or on the edge of, the Pacific plate. We hope in this way to confine our propagation paths to lie entirely within the Pacific plate and to avoid any effects produced by the propagation of surface waves across a major continental boundary. Third, we have used only well recorded earthquakes, rejecting both small events with a poor signal-to-noise ratio and large events which are clipped or distorted.

The selected seismograms were digitized at irregular intervals and a digitization interval of either 1.0 or 2.0 sec was then obtained by linear interpolation. Multiple-filter analysis in the frequency domain (Dziewonski *et al.* 1969) yielded spectral amplitudes and group velocities for both Rayleigh waves and Love waves. Data were obtained for the period range 18 to 110 sec and 20 to 110 sec for Rayleigh and Love waves, respectively. The vertical component seismogram was used for the Rayleigh-wave determinations, and the transverse component, as obtained from a coordinate transformation of the north-south and east-west components, was used for the Love waves. At the shorter periods, some ambiguity arises in the identification of the fundamental Love mode because of the presence of substantial higher-mode energy. Whenever there was any uncertainty as to which amplitude maximum corresponded to the fundamental mode, that maximum which most closely corresponded to the appropriate group velocity value of Yu and Mitchell (1978) was taken to be the fundamental mode. It is probable, however, that in cases where the fundamental and higher modes are not clearly separated, that the fundamental-mode amplitude values suffer from distortion due to higher-mode contamination.

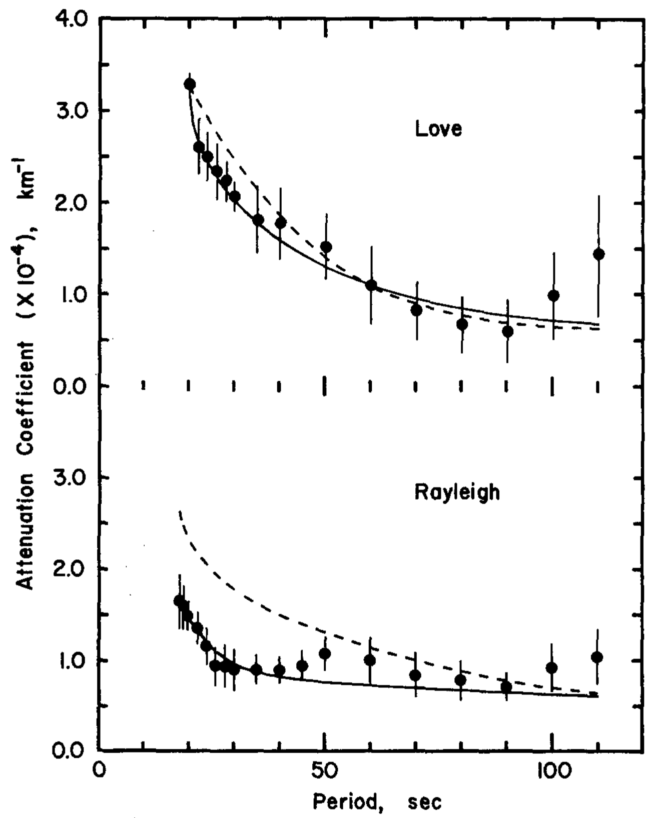

FIG. 2. Average observed Love- and Rayleigh-wave attenuation coefficients. The solid lines indicate the fit of the model obtained from an inversion of the total data set (Figure 5), and the dashed lines indicate theoretical values for the model of Mitchell (1976) obtained for a larger, and on average, younger, region of the Pacific.

Attenuation coefficients, as well as interstation phase and group velocities, were determined. The attenuation coefficient values and values of Q computed from them are discussed in the following section.

The phase and group velocities were compared with the recent results of Yu and Mitchell (1978) which were obtained for more than 30 paths in the Pacific. The comparison showed very good agreement between the two independent sets of data. As reported by several authors, regionalization of the group and phase velocities for Rayleigh waves indicate that they both increase with increasing age of the oceanic lithosphere.

Average Attenuation Coefficients

Using the two-station method, we have determined the attenuation coefficients for the fundamental Rayleigh and Love modes using the events described in Table 1 and Figure 1. The working expression for the two-station method is

$$\gamma(\omega) = \frac{\ln\left[\dfrac{A_1(\omega, r_1)I_2(\omega)(\sin \Delta_1)^{\frac{1}{2}}}{A_2(\omega, r_2)I_1(\omega)(\sin \Delta_2)^{\frac{1}{2}}}\right]}{r_2 - r_1}$$

where $\gamma(\omega)$ is the attenuation coefficient at each angular frequency ω, A_1 and A_2 are observed spectral amplitudes at distances r_1 and r_2, I_1 and I_2 are instrumental

TABLE 2

Inter-Station Group Velocities, Phase Velocities, and Attenuation Coefficients

T (sec)	U_R (km/sec)	C_R (km/sec)	U_L (km/sec)	C_L (km/sec)	γ_R ($\times 10^{-4}$) (km^{-1})	γ_L ($\times 10^{-4}$) (km^{-1})	Q_R	Q_L
18	3.555	3.946			1.64 ± 0.30		299	
19	3.583				1.58 0.23		292	
20	3.693	3.941	4.233	4.164	1.47 0.15	3.30 ± 0.07	289	112
22	3.773	3.970	4.217	4.242	1.34 0.17	2.63 0.30	282	129
24	3.865	3.981	4.256	4.300	1.13 0.19	2.48 0.24	300	124
26	3.884	3.994	4.339	4.347	0.94 0.21	2.34 0.29	331	112
28	3.932	4.005	4.362	4.418	0.93 0.23	2.23 0.18	307	115
30	3.971	4.006	4.407	4.450	0.89 0.22	2.08 0.14	296	114
35	4.005	4.009	4.400	4.474	0.91 0.15	1.80 0.35	246	113
40	4.011	4.009	4.405	4.524	0.90 0.13	1.77 0.38	217	101
45	4.007		4.417		0.94 0.14	1.52 0.30	185	104
50	4.007	4.007	4.439	4.540	1.08 0.17	1.49 0.35	146	95
60	3.990	4.007	4.429	4.552	1.01 0.23	1.09 0.42	130	108
70	3.945	4.021	4.401	4.556	0.84 0.24	0.82 0.32	136	124
80	3.902	4.041	4.427	4.597	0.79 0.19	0.66 0.29	127	134
90	3.874	4.074	4.479	4.634	0.72 0.14	0.60 0.34	125	130
100	3.829	4.107	4.450	4.650	0.92 0.23	1.00 0.47	90	71
110	3.839		4.413		1.07 0.29	1.45 0.64	70	45

responses for seismographs at the two stations. The factors sin Δ_1 and sin Δ_2 provide corrections for geometrical spreading. Instrumental corrections were applied using theoretical values for WWSSN instrument responses. We inspected the calibration pulse on each record to assure that the response did not deviate greatly from theoretical values. A portion of the scatter in our data, however, undoubtedly is produced by instrumental effects.

Figure 2 presents the average Love- and Rayleigh-wave attenuation coefficients obtained for the combined data of all paths used in this study. The same information, as well as the average phase and group velocities obtained in this study appears in Table 2. Corresponding Q values were calculated using the expression $Q = \pi/UT\gamma$, where U denotes the group velocity for surface waves with period T. The attenuation coefficient values are similar to the values of Mitchell *et al.* (1976) at the longer periods, but become lower than the values of those authors in the shorter period range. This difference can be explained by considering the regions over which data were obtained in the two studies. The data of Mitchell *et al.* (1976) were obtained for a very broad portion of the Pacific, including numerous paths across the young eastern Pacific and east Pacific rise to South American stations. Data of the present study are predominantly from older regions of the Pacific, the only station in the eastern Pacific being GIE in the Galapagos Islands. Although a few paths partly traverse the younger eastern Pacific region, no paths entirely cross the east Pacific rise. The large number of paths through the highly attenuating young portion of the Pacific probably cause the average Pacific values of Mitchell *et al.* (1976) to be higher than the values of the present study which pertain predominantly to older regions of the Pacific.

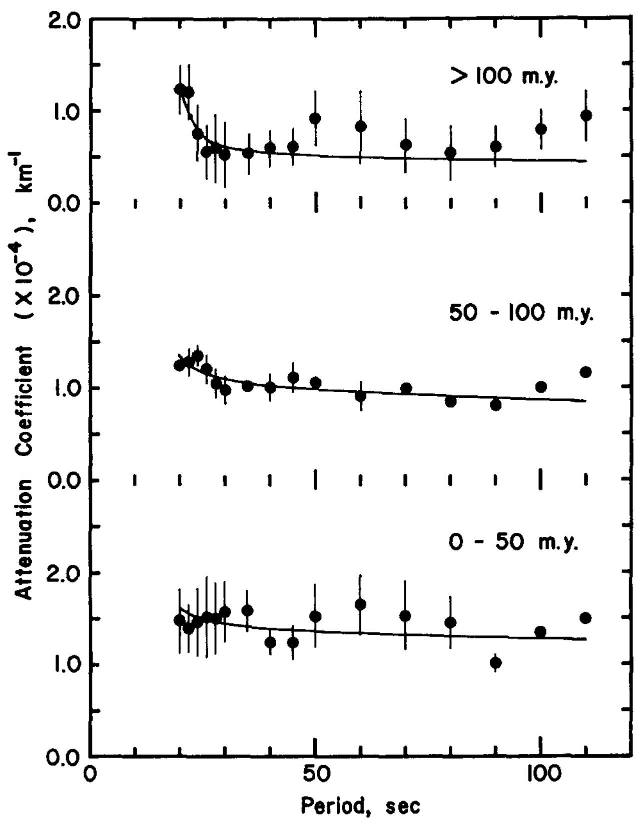

FIG. 3. Rayleigh-wave attenuation coefficients obtained for regions of the Pacific separated by age (0 to 50 m.y., 50 to 100 m.y., >100 m.y.). The solid lines are theoretical values corresponding to the models of Figure 7.

REGIONALIZED ATTENUATION COEFFICIENTS

It has been common in studies of surface-wave velocities in the Pacific to divide the Pacific into a number of regions, each characterized by a different average age (e.g., Kausel *et al.* 1974; Schlue and Knopoff, 1977; Yu and Mitchell, 1978). The boundaries have been taken to coincide with isochrons which have been inferred from geomagnetic lineations. We have followed the same procedure; however, because of the substantial scatter inherent in amplitude studies, we have divided the Pacific into only three regions, instead of four or more as done by the above authors. The age ranges of the three regions are 0 to 50, 50 to 100, and greater than 100 million years of age.

The attenuation coefficients have been regionalized by using the expression

$$\gamma_R = \sum_{i=1}^{n} \alpha_i \gamma_{Ri}$$

where n is the number of regions traversed, α_i is the ratio of path length in region i to the total path length, γ_R is the average Rayleigh-wave attenuation coefficient value for the total path-length between stations, and γ_{Ri} is the Rayleigh-wave attenuation coefficient in each of the traversed regions. Since γ_R and α_i are known quantities, the γ_{Ri} values can be determined by linear least-squares. For the present

TABLE 3

RAYLEIGH WAVE ATTENUATION COEFFICIENTS, GROUP VELOCITIES, AND Q, FOR THREE AGE REGIONS OF THE PACIFIC

Period(s)	0–50 m.y.				50–100 m.y.				>100 m.y.			
	U_R* (km/sec)	γ_R (km^{-1})		Q_R	U_R* (km/sec)	γ_R(km^{-1})		Q_R	U_R* (km/sec)	γ_R (km^{-1})		Q_R
20	3.755	1.48 ±	0.36	282.6	3.811	1.25 ±	0.01	329.7	3.544	1.25 ±	0.26	354.6
22	3.785	1.40	0.25	269.5	3.893	1.28	0.13	286.6	3.658	1.21	0.29	322.6
24	3.815	1.47	0.37	233.4	3.974	1.35	0.10	244.0	3.771	0.77	0.29	450.8
26	3.823	1.51	0.43	209.3	4.014	1.20	0.14	250.9	3.833	0.54	0.29	583.8
28	3.830	1.49	0.38	196.6	4.054	1.03	0.14	268.7	3.894	0.60	0.37	480.2
30	3.764	1.57	0.32	177.2	4.074	0.97	0.10	265.0	3.930	0.53	0.36	502.8
35	3.827	1.58	0.20	148.4	4.111	1.02	0.04	214.1	3.999	0.54	0.22	415.7
40	3.806	1.22	0.09	169.1	4.116	1.01	0.14	188.9	4.044	0.59	0.18	329.2
45	3.785	1.23	0.17	150.0	4.102	1.11	0.15	153.3	4.066	0.62	0.20	276.9
50	3.762	1.52	0.34	109.9	4.088	1.07	0.05	143.6	4.070	0.92	0.29	167.8
60	3.734	1.64	0.33	85.5	4.035	0.91	0.15	142.6	4.055	0.83	0.39	155.6
70	3.696	1.52	0.37	79.9	3.993	0.99	0.00	113.5	4.007	0.62	0.29	180.7
80	3.666	1.44	0.26	74.4	3.944	0.85	0.01	117.1	3.956	0.55	0.29	180.5
90	3.665	0.99	0.07	96.2	3.875	0.81	0.01	111.2	3.918	0.62	0.21	143.7
100	3.631	1.35	0.01	64.1	3.839	1.01	0.01	81.0	3.892	0.80	0.20	100.0
110	3.591	1.49	0.01	53.4	3.803	1.18	0.00	63.6	3.865	0.96	0.27	77.0

* Group velocity values taken from Yu and Mitchell (1978). Values for the 0 to 50 m.y. region represent an average for the 0 to 20 m.y. and 20 to 50 m.y. regions of those authors. For periods not listed by Yu and Mitchell (1978), we have inserted values which assume linear variation between given group-velocity values.

study, we solved for γ_{R1}, γ_{R2}, and γ_{R3}, corresponding to the age regions 0 to 50 m.y., 50 to 100 m.y., and >100 m.y., respectively.

The regionalized values of γ_{Ri} and their standard deviations appear in Figure 3. Table 3 presents the regionalized values of γ_{Ri} along with the phase and group velocities of Yu and Mitchell (1978) for those regions, and the corresponding Rayleigh-wave Q values. Although scatter is present in the data, it is apparent from Figure 3 that the older regions of the Pacific are characterized by lower attenuation coefficient values than are the younger regions. At the longer periods, the average attenuation coefficient value is about 1.4×10^{-4} km^{-1} for the youngest region (0 to 50 m.y.), about 1.0×10^{-4} km^{-1} for the 50 to 100 m.y. region, and about 0.6×10^{-4} km^{-1} for the oldest region (>100 m.y.). The following section will present models of Q_β^{-1} for the three regions of the Pacific which will indicate the depth ranges over which changes in anelastic properties occur.

Figure 4 presents the attenuation coefficient data for the youngest and oldest regions on the same plot, and compares these with values obtained for the eastern

Pacific by Mitchell *et al.* (1976). Data from that study are presented for periods greater than 20 sec for a broad portion of the eastern Pacific and also for a single path along the east Pacific rise. The data of the present study show a definite increase in attenuation with decreasing age of the Pacific sea floor. Although the standard deviations for the 50 to 100 m.y. region usually overlap at least one of the other regions, no overlap occurs between the data of the youngest and oldest region at most periods.

Average values for the eastern Pacific (Mitchell *et al.,* 1977) are characterized by very large standard deviations. A plot of those values, however, shows that they are substantially higher than those of the present study throughout the entire period

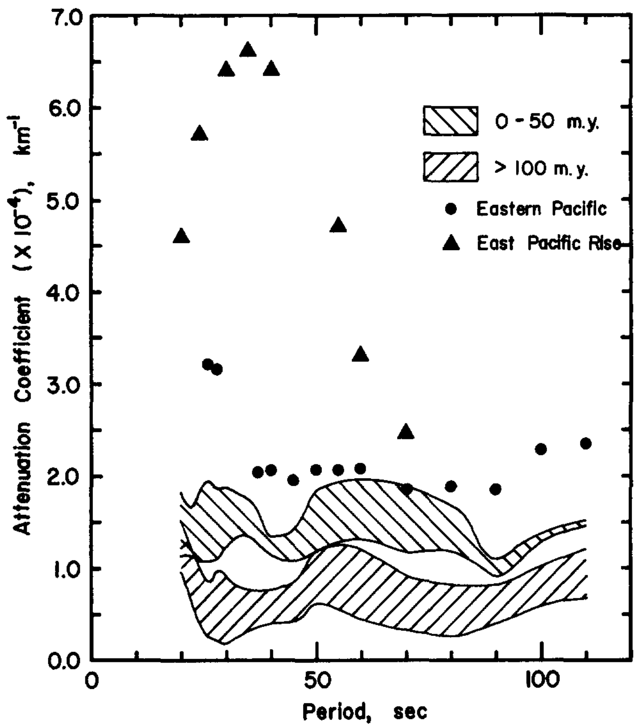

FIG. 4. Comparison of Rayleigh-wave attenuation coefficients obtained for regions of 0 to 50 m.y. age and >100 m.y. age with those obtained by Mitchell *et al.* (1977) for a broad portion of the eastern Pacific and for the east Pacific rise. The latter two groups of data are characterized by large confidence limits which are not shown.

range, and data from a single path along the east Pacific rise indicate extremely high attenuation. Figure 4 suggests that a decrease in the attenuative properties (or an increase in Q) occurs within the crust and/or upper mantle of the Pacific with increasing age of the sea floor, with the change being most rapid in the youngest regions. After a few tens of millions of years the change in anelastic properties appears to be less rapid. It will be important for our understanding of the evolution of the Pacific plate if high-quality attenuation data, with small confidence limits, can be obtained for subregions of the eastern Pacific.

Q_β^{-1} MODELS

Average Pacific anelasticity models for the crust and upper mantle beneath the Pacific have been determined by Mitchell (1976) using methods of modern inversion theory (Backus and Gilbert, 1970) in stochastic form (Der *et al.* 1970; Jordan and Franklin, 1971). Data for those inversions were obtained for a broad region of the Pacific, including numerous paths across the young eastern Pacific. The attenuation data of the present study pertain predominantly to older regions and, consequently, exhibit lower values than those used in that inversion. We have inverted the data of

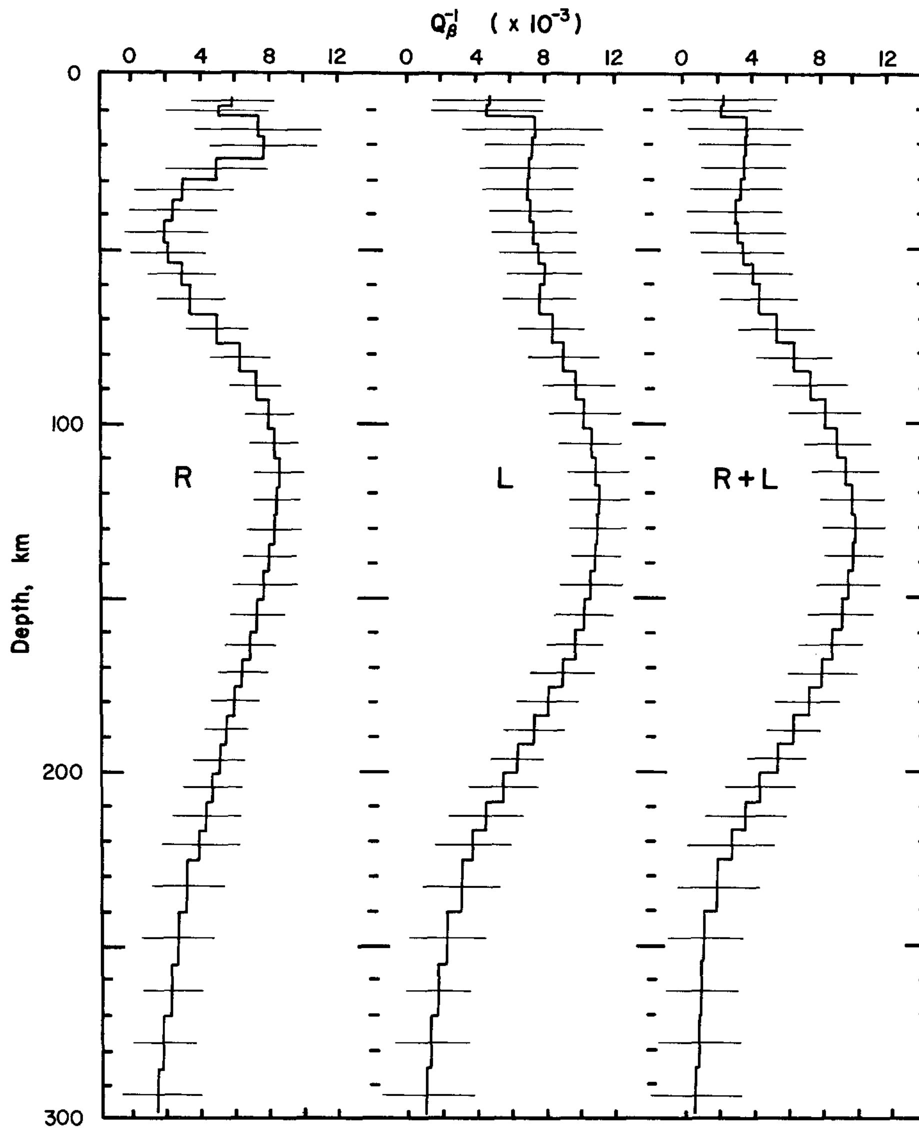

FIG. 5. Q_β^{-1} models and standard deviations for the Pacific obtained from the average data of Figure 2 and Table 2. Separate inversions were made using the Rayleigh-wave data only, the Love-wave data only, and the combined Rayleigh-Love data.

Figure 2 to obtain average Q_β^{-1} models of the Pacific, weighted toward the older regions, and also have inverted the regionalized Rayleigh-wave attenuation data of each region in Figure 3.

Inversions of the combined Rayleigh- and Love-wave attenuation data, as well as of the Rayleigh-wave data alone and the Love-wave data alone were conducted.

The inversion procedure employs the equations of Anderson *et al.* (1965) which assume that Q_β^{-1} is independent of frequency over the period range of interest. That range in the present case is between 20 and 110 sec. Since surface-wave amplitudes are relatively insensitive to Q_α, we have assumed that Q_α is twice as large as Q_β for all inversions (Anderson *et al.,* 1965).

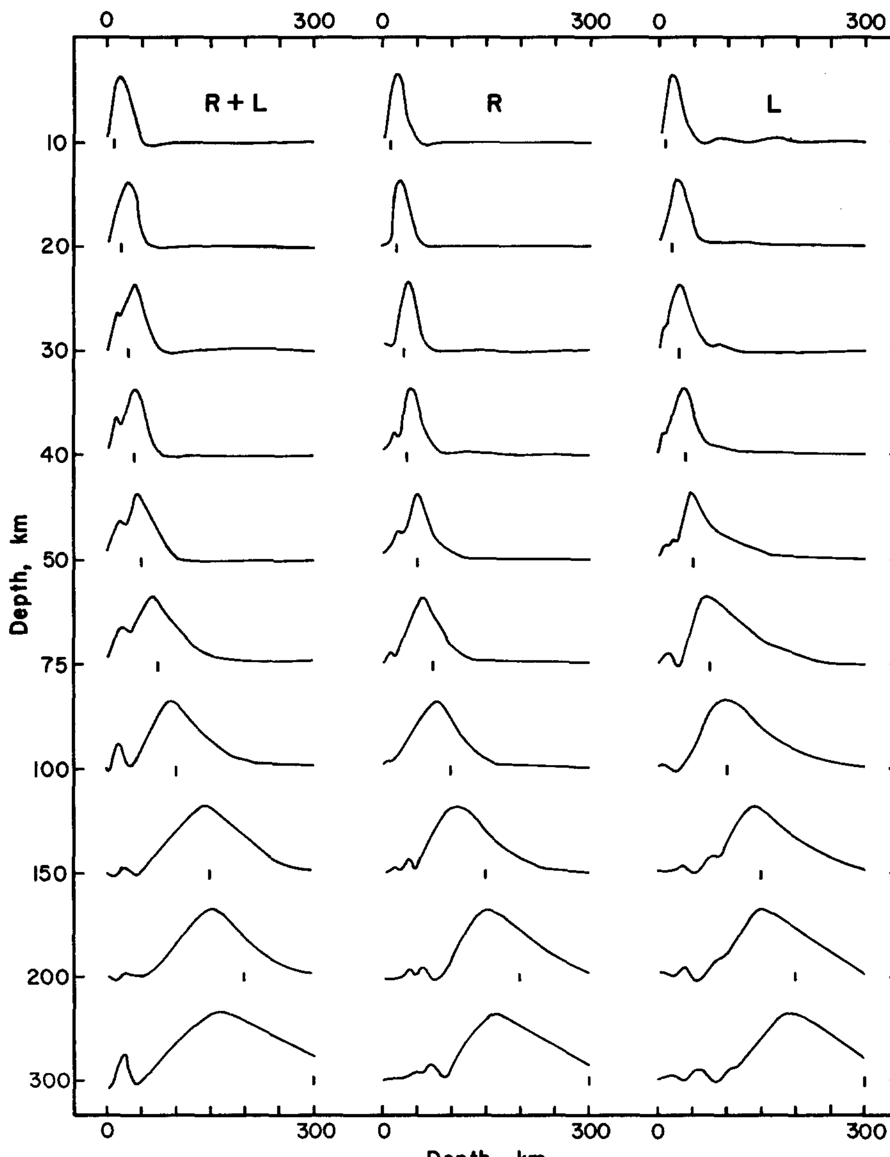

FIG. 6. Resolving kernels for the models of Figure 5. The depth which each of them refers to is indicated by the number beside, and by the vertical dash below, each kernel.

Average Pacific models obtained from the inversion of Rayleigh waves, Love waves, and the combined Love- and Rayleigh-wave data appear in Figure 5 along with the model standard deviations. The corresponding resolving kernels for each inversion appear in Figure 6. The velocity model from which the partial derivatives for the inversion process were computed is model 8-1-2 of Saito and Takeuchi (1966). Although some differences occur between the models obtained in the three inversions, there is much overlap in the standard deviation bars. This overlap, as well as the breadth of the resolving kernels in Figure 6 lead us to conclude that the differences between the models of Figure 5 are not significant. It also indicates that

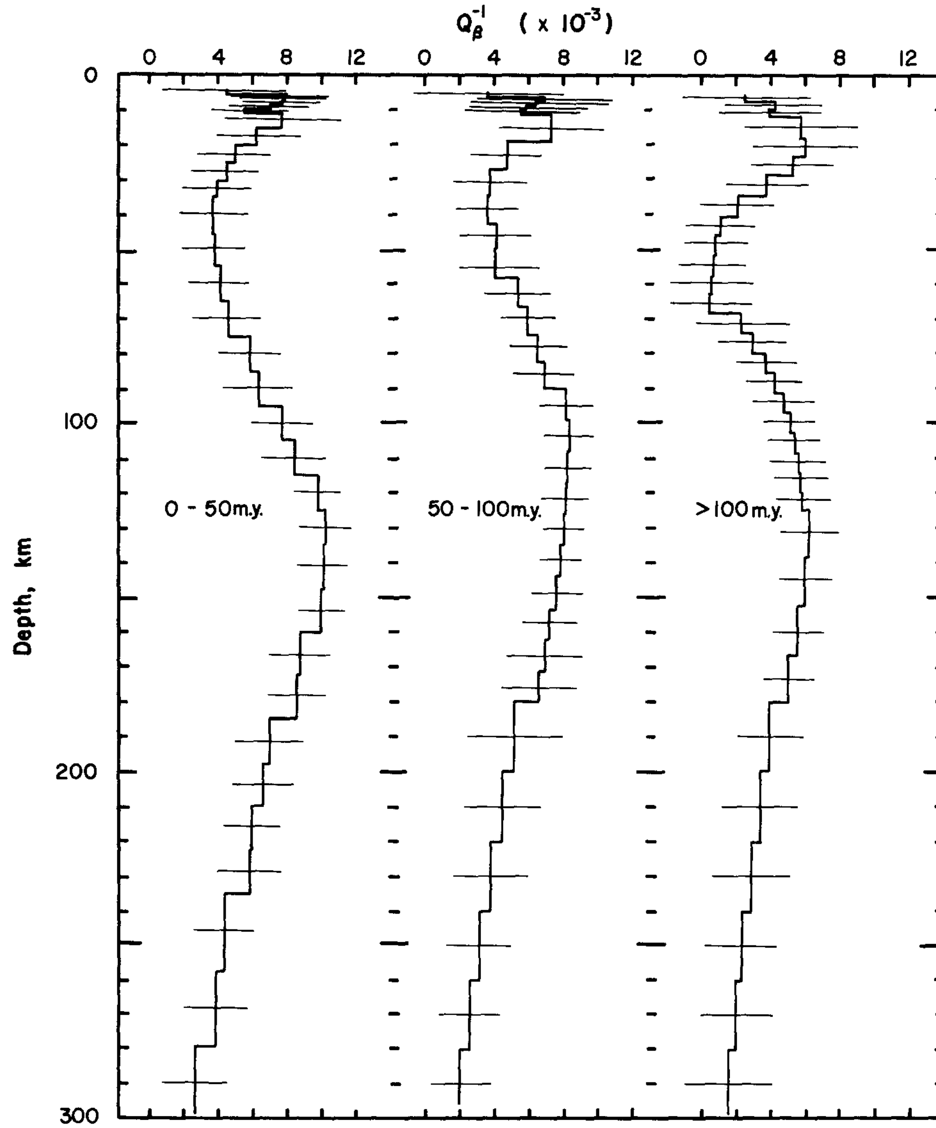

FIG. 7. Q_β^{-1} models and standard deviations for regions of the Pacific corresponding to ages of 0 to 50 m.y., 50 to 100 m.y., and >100 m.y. These were obtained by inverting the data of Figure 3 and Table 3.

higher-mode contamination, although bothersome, does not rule out the use of Love-wave amplitudes for attenuation studies. Common features of all models are a Q_β^{-1} increase (or decrease in Q_β) at depths of 50 to 60 km, a maximum at depths of 120 to 130 km, and a return to values similar to those at 50 km at depths of about 200 km. The depths to the top and bottom of this low Q zone (50 and 200 km) are similar to those obtained by Mitchell (1976). Theoretical attenuation coefficients for the model obtained from the combined Love- and Rayleigh-wave data appear in Figure 2, along with the observed data. The fit appears to be reasonably good, with only the data at the longest periods and two other points differing from the theoretical values by more than one standard deviation.

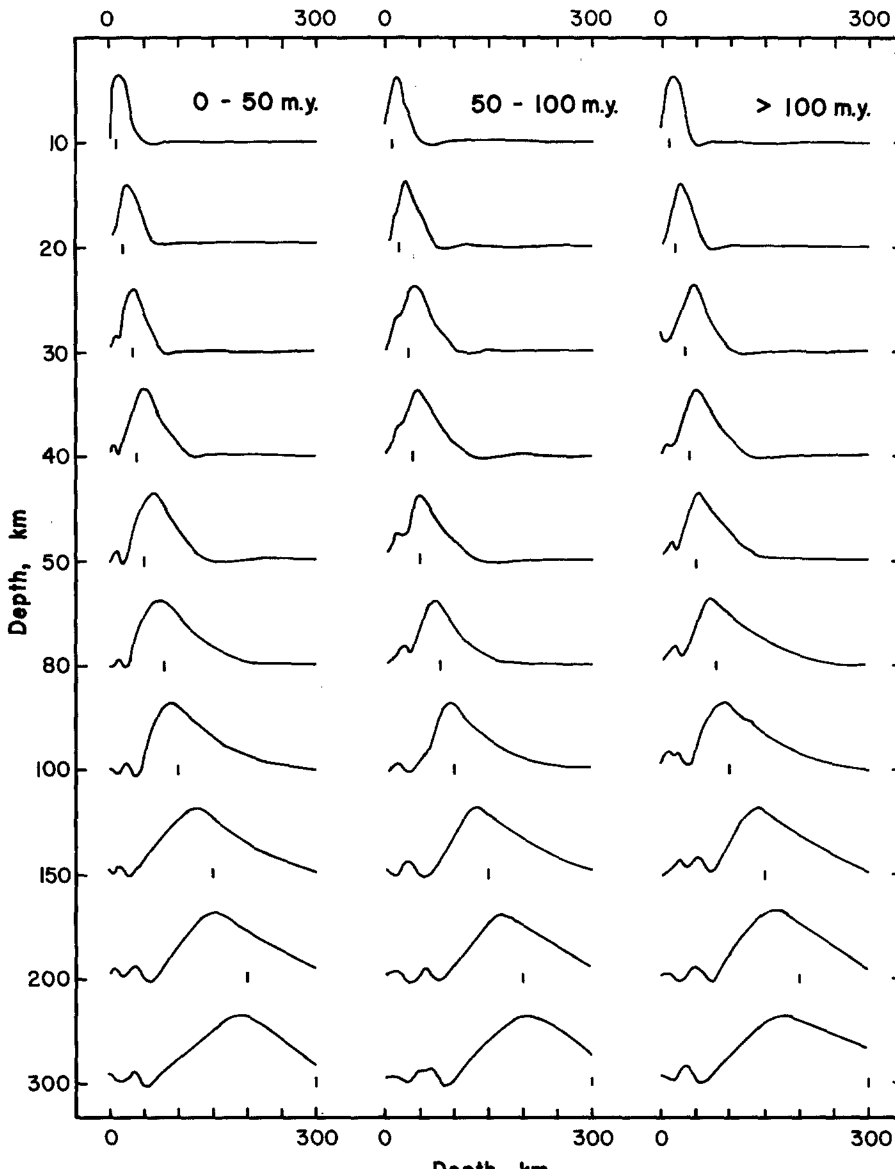

FIG. 8. Resolving kernels for the models of Figure 7.

Models from the regionalized Rayleigh-wave data appear in Figure 7 and the resolving kernels for each of the models are plotted in Figure 8. The velocity models from which partial derivatives were calculated for these inversions are those of Yu and Mitchell (1978). Common features of these models are: (1) low Q values in the upper lithosphere ($Q_\beta \simeq 125$ to 170) at depths between about 10 and 20 km, (2) an increase in Q_β (or decrease in Q_β^{-1}) to depths between 30 and 40 km, (3) a decrease in Q_β (or increase in Q_β^{-1}) to a minimum at depths between 100 and 150 km, and (4) an increase in Q_β (or decrease in Q_β^{-1}) at greater depths.

A systematic decrease in Q_β^{-1} (or increase in Q_β) appears to occur at almost all depths with increasing age. A close examination of the models, however, indicates that these apparent changes with age cannot always be resolved. Because of the large overlap of the standard deviation bars for the youngest and oldest regions with that of the 50 to 100 m.y. model, it is convenient to only compare features of the 0 to 50 m.y. model with those of the >100 m.y. model. The only depth range over which the standard deviations of those two models do not overlap, occurs in the low Q zone centered at a depth of about 130 km. However, it appears likely that Q in the lithosphere also increases with age of the Pacific sea floor, since little overlap of the standard deviation bars occurs at that depth and the resolving kernels are relatively narrow. The resulting models also suggest that the depth to the top of the low Q zone increases with increasing age. However, this conclusion cannot definitely be established because of the limited resolution which is associated with these models.

Theoretical Rayleigh-wave attenuation coefficients for the three models are plotted along with the data in Figure 3. The fit in each case is reasonably good; it is clear that the models adequately explain the decreasing attenuation coefficient values with increasing age of the Pacific sea floor.

CONCLUSIONS

Average Rayleigh-wave attenuation coefficients for the Pacific were found to decrease from 1.64×10^{-4} km^{-1} at a period of 18 sec to values less than 1.0×10^{-4} km^{-1} at periods out to 110 sec. The Love-wave values range between 3.30×10^{-4} km^{-1} and 0.60×10^{-4} km^{-1} at periods between 20 and 110 sec, the lower values occurring at longer periods. Both data sets, especially that of Love waves, are characterized by relatively large standard deviations. These attenuation coefficient values are lower at shorter periods than the data of Mitchell *et al.* (1976). This difference can be explained by the fact that surface-wave paths used in the present study pertain predominantly to older parts of the Pacific, whereas the data of Mitchell *et al.* (1976) include numerous paths across the young eastern Pacific and east Pacific rise. Q_β^{-1} models obtained from these data include a low Q zone at depths between 50 and 200 km.

Attenuation data which has been regionalized to correspond to portions of the Pacific sea floor having ages of 0 to 50, 50 to 100, and >100 million years exhibits a systematic decrease with increasing age of the lithosphere. Although there is much overlap of the attenuation data at one standard deviation, clear differences are apparent between the youngest and oldest regions. Q_β^{-1} models for each region indicate that Q_β in the low Q zone increases with increasing age of the sea floor above it, and that Q_β in the lithosphere may also increase with age. The lithosphere of all models is characterized by relatively low values overlying higher values. A low Q zone underlies the lithosphere in all regions and extends to depths near 200 km.

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