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SHALLOW ATTENUATION IN THE WEST CORINTH-PATRAS RIFT, GREECE

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The study of spectral characteristics of earthquakes is of paramount importance to an understanding of source processes, path effects and seismic response due to local geology. The area where the present investigation took place is located towards the northwestern end of the Corinth graben. In this area, the E-W–faulting trend of the Corinthian graben intersects the more NW-SE trend of basins associated with subduction. It is one of the most seismically active regions in Greece (Tselentis and Makropoulos, 1986), and it has been selected as an earthquake prediction test site. More than 10 physical parameters, ranging from acoustic emission to variations of the Earth's electric field, are continuously monitored by Patras University seismological network.

Since it is well documented that the source characteristics of small earthquakes are difficult to understand due to the path and site effects, it is important to try to delineate these effects prior attempting to correlate the various precursor signals with source processes. Acceleration spectra at high frequencies were analyzed to make an estimation of the spectra decay parameter k in the region.

In the present investigation, we followed the approach of Anderson and Hough (1984), who modeled the acceleration spectra decay by the equation

$$a(f, r) = Cf^2 \frac{2}{1 + \left(\frac{f}{f_c}\right)^2} e^{-\pi k(r) f}, \tag{1}$$

where f is frequency, f_c is the corner frequency, r is the hypocentral distance, and c is a constant. $k(r)$ is estimated from the shape of observed spectra and can affect estimates of the source controlled corner frequency (Boore, 1986). The form of this equation when plotted in a semi-logarithmic plot follows a linear trend beyond the corner frequency with a slope given by

$$s = -\pi k \log_{10} e. \tag{2}$$

Investigations (e.g., Rebollar *et al.*, 1980; Anderson and Hough, 1984) have indicated that k grows with source-to-station distance following (as a first-order approximation) a linear relationship given by

$$k(r) = k_0 + yr. \tag{3}$$

According to this model, k_0 represents a site effect due to the near-surface attenuation (in the weathered layer) close to the recording station or a source effect, and the slow increase with distance measured by the slope dk/dr is a regional effect that describes wave path attenuation during lateral propagation. An ω^2 source model (equation 1) and Q that is independent of frequency but increases with depth would explain the results.

INSTRUMENTATION AND DATA ANALYSIS

Data used in this study were recorded by Patras University short-period digital seismic network (Fig. 1). The network consists of six stations, all of them with vertical component seismometers operating at 90 dB dynamic range and in

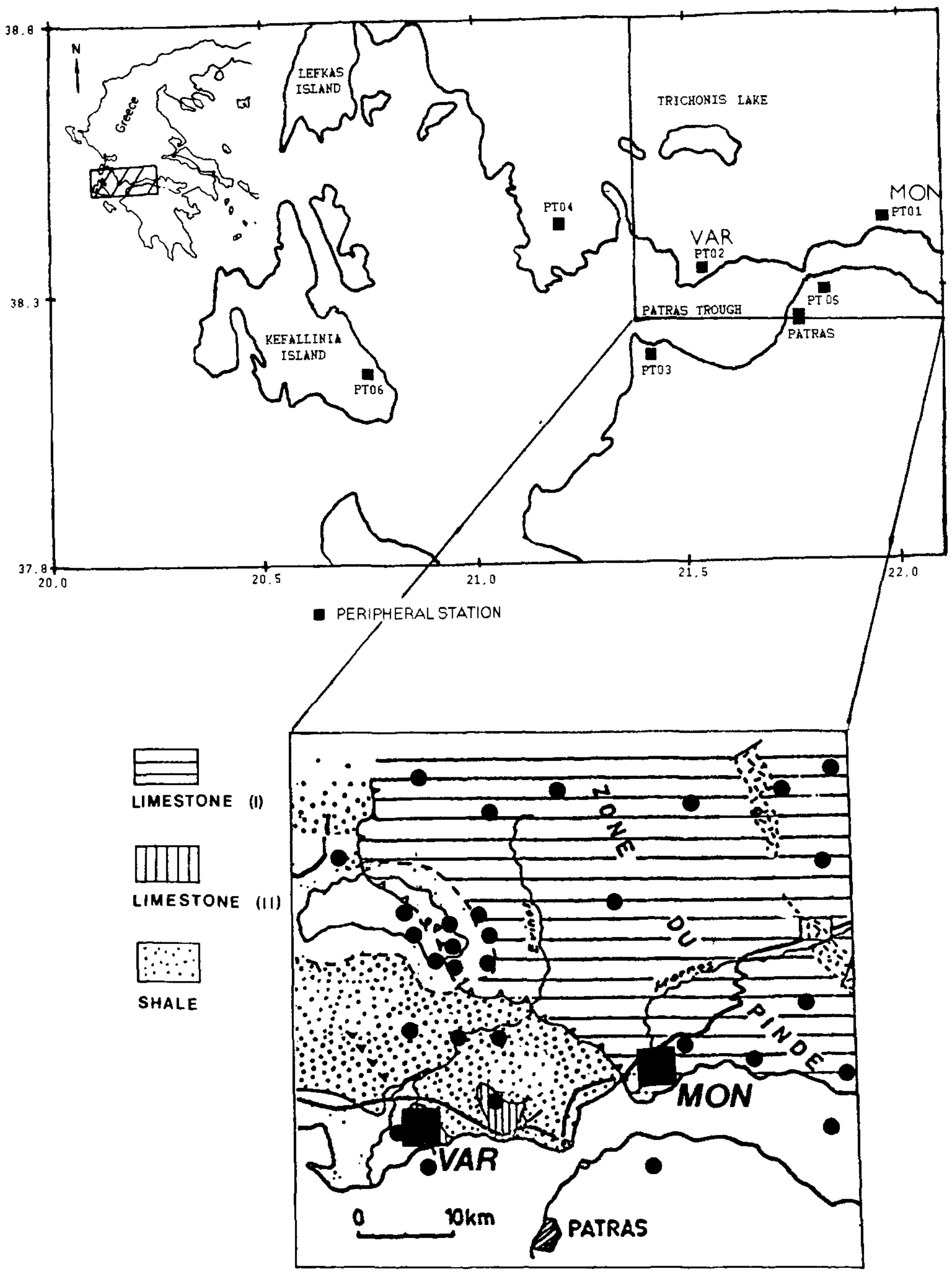

FIG. 1. Layout of the microearthquake network (solid squares), locations of the microearthquakes used (circles), and the main geological features.

a low-noise environment. All of them use 1-Hz Teledyne Geotech S-13 vertical seismometers. The signals are radio-telemetered via FM subcarriers to the central recording site at Patras seismological center in real time. There, each channel signal is filtered for aliasing with a 30-Hz Butterworth lowpass filter, samples at 100 sps and converted to digital form with a resolution of 16 bits.

The hardware of the data acquisition system consists of a digital data acquisition system PDAS100 by Teledyne Geotech that uploads the digital data to a WYSE-7000 mini computer where all the processing is being carried out.

Initially 79 earthquakes (corresponding to the 3 months of operation of the network) were selected on the basis of a first rough visual inspection. This first selection was carried out by selecting any earthquake that was recorded in at least 5 stations with magnitude greater than 1.5, location RMS less than 0.1, and epicenters lying within the test site. A further discrimination shortened the sample of events by analyzing the signal-to-noise ratio, taking those seismograms with that a signal-to-noise ratio greater than 5 at stations VAR and

TABLE 1
DATA ON MICROEARTHQUAKES USED

Year	Month	Day	Time	Latitude	Longitude	Depth	M_L
1992	JAN	03	21 57 04.1	38.42	21.86	07	2.1
1992	JAN	04	00 21 30.7	38.40	21.99	08	2.5
1992	JAN	04	16 15 27.3	38.31	21.57	16	2.2
1992	JAN	11	12 20 21.0	38.41	21.72	07	1.6
1992	JAN	16	13 09 04.8	38.51	21.95	06	2.0
1992	JAN	16	21 36 01.1	38.31	21.82	09	3.0
1992	JAN	18	16 26 08.7	38.34	21.87	07	3.0
1992	JAN	19	20 57 52.8	38.33	21.84	07	3.3
1992	JAN	22	05 30 24.9	38.37	21.96	08	2.4
1992	JAN	26	22 48 43.5	38.30	21.30	07	2.8
1992	JAN	30	00 48 03.2	38.32	21.84	07	2.9
1992	FEB	01	05 46 55.0	38.35	21.71	07	2.5
1992	FEB	02	21 32 54.5	38.40	21.68	05	2.5
1992	FEB	04	03 56 07.5	38.33	21.53	11	3.1
1992	FEB	05	09 33 17.4	38.52	21.65	07	2.9
1992	FEB	06	08 21 34.2	38.35	21.91	07	3.3
1992	FEB	07	00 29 05.8	38.47	21.66	08	3.0
1992	FEB	07	00 00 07.0	38.48	21.68	07	3.1
1992	FEB	07	14 15 12.1	38.52	21.61	07	3.3
1992	FEB	07	23 41 13.6	38.53	21.62	06	2.8
1992	FEB	08	00 54 48.8	38.45	21.65	09	3.0
1992	FEB	08	12 00 33.0	38.64	21.86	07	2.6
1992	FEB	08	13 56 27.5	38.54	21.61	07	2.5
1992	FEB	12	20 29 10.3	38.54	21.64	07	2.8
1992	FEB	12	22 08 33.9	38.54	21.64	08	3.0
1992	FEB	13	13 20 26.0	38.53	21.65	14	2.8
1992	FEB	13	15 36 44.0	38.54	21.60	12	3.3
1992	FEB	13	15 36 44.0	38.32	21.36	09	3.5
1992	FEB	15	02 04 29.7	38.35	21.86	06	3.0
1992	FEB	15	20 47 48.0	38.35	21.86	06	3.0
1992	FEB	16	10 15 43.7	38.35	22.00	07	3.0
1992	FEB	16	11 30 12.7	38.30	21.78	08	2.6
1992	MAR	15	02 47 08.6	38.23	21.50	11	2.4
1992	MAR	22	00 14 34.0	38.34	21.43	09	2.4

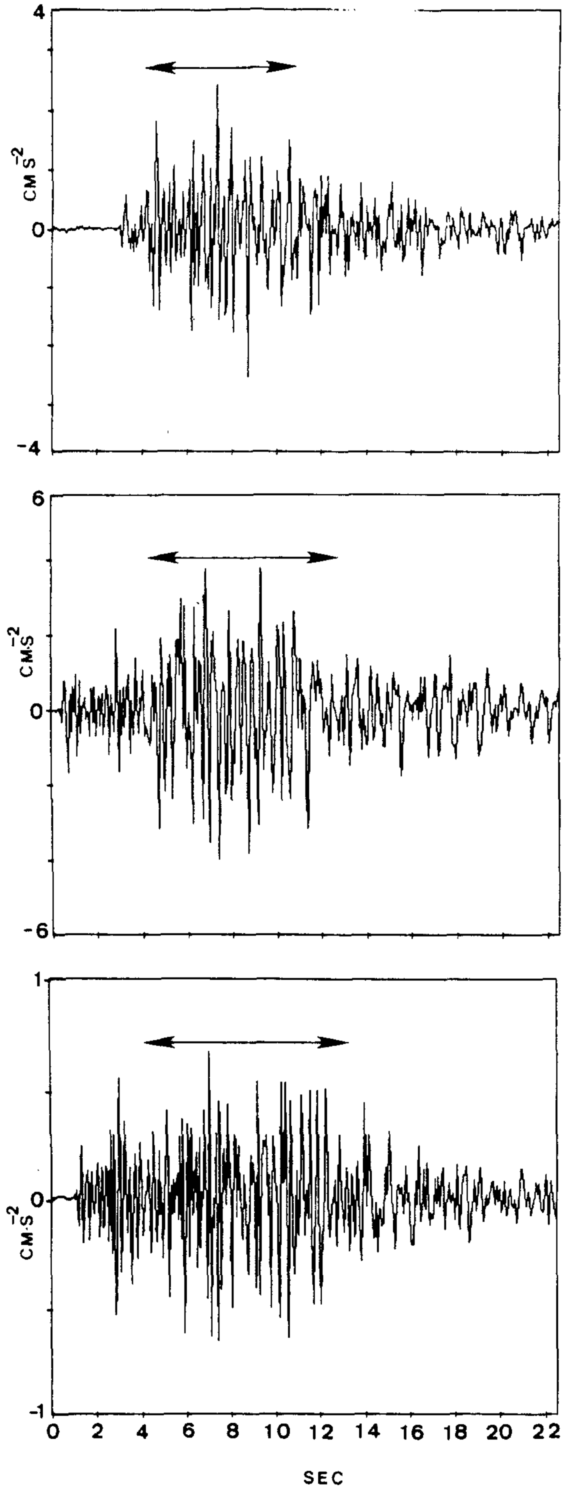

FIG. 2. Seismograms recorded at station MON and corrected for instrument response. The time window used in the spectral analysis is shown by arrows.

MON, both located on hard rock (limestones). In this way, only events occurring inside or near the borders of the network and covering the region (Fig. 1) were chosen, a total of 56 earthquakes. A basic assumption in the analysis is that the corner frequencies of the selected events are small compared to the frequencies over which the spectra were fitted. To fulfill this requirement, we selected only those events for which the corner frequencies were found less or equal to 10 Hz. In total, 32 events were finally selected and are presented in Figure 1 and Table 1, corresponding to a total of 64 analyzed seismograms.

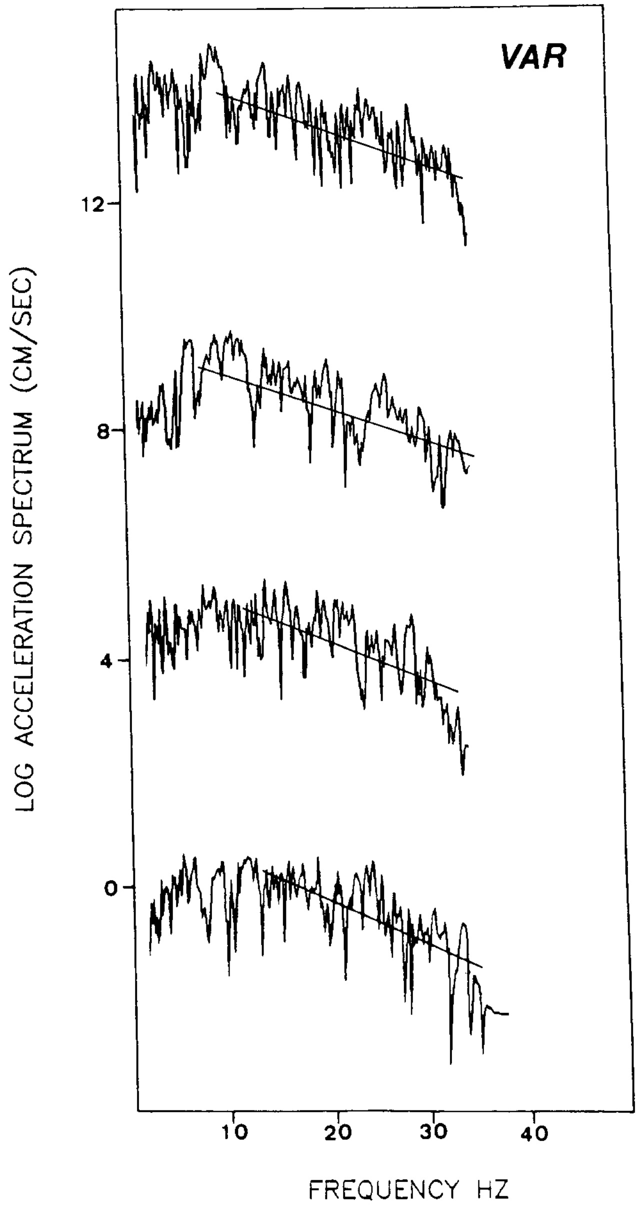

FIG. 3. S-wave acceleration spectra. Superimposed on each spectrum are the corresponding linear least-square fits.

Figure 2 shows examples of typical seismograms used in this study. Time windows that include the main s-wave pulses and coda waves were chosen to calculate spectra. These spectra were corrected for instrument response and transformed to acceleration spectra. Figure 3 shows examples of plots of acceleration spectra at station VAR. This figure clearly shows amplitude decays of the spectra at frequencies between 8 and 25 Hz. The corner frequencies of the events considered in this study are in the range of 1 to 10 Hz. Plots of k values versus distance were prepared and are presented in Figure 4. Both stations show a weak linear behavior of k with distance, suggesting a diminution of attenuation with depth in the crust.

The results of least square fits of k versus hypocentral distance are presented in Figure 4. k_0 values were found to range from 36.2 ± 25.3 msec with a slope of 0.11 ± 0.06 msec/km for station MON to 44 ± 18.8 msec with a slope of 0.13 ± 0.08 msec/km for station VAR. The generalized surficial geology where the two stations were located consists mainly of limestones separated by various faults. Unconsolidated sediments and some shales are scattered in the valleys between the scraped ranges. k_0 values estimates in this study are characteristic of rock. The large value of the standard error of the mean indicates that lateral variations of frequency-independent Q exist in the crust of the investigated region and is compatible with the prevailing complex tectonic regime.

It has been reported in other studies that k depends upon local geology conditions. Anderson and Hough (1984) give a value of k_0 of 40 msec for rock stations in California region, Hough *et al.* (1988) give values between 0.3 to 3.5 msec for stations on very competent rock in the same region, and Rebollar

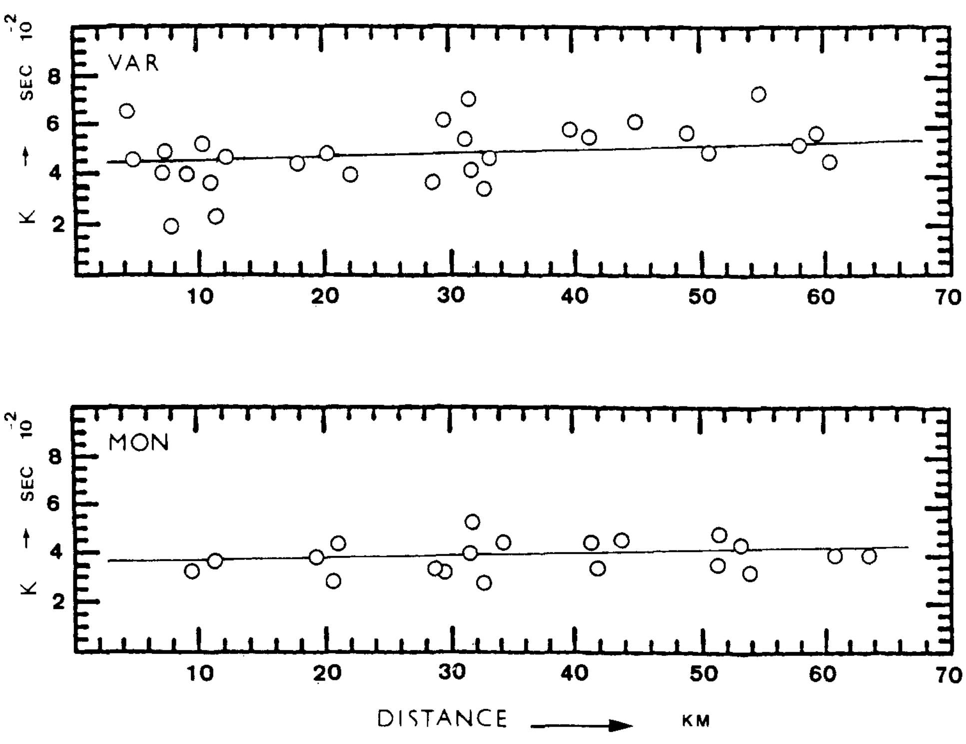

FIG. 4. Values of k versus epicentral distance for stations VAR and MON with best-fit lines.

(1990) determines values of 2.5 to 3.3 msec for stations on the northern Baja California batholith. Rebollar *et al.* (1990) give values between 15.7 to 34.7 msec for crystalline rocks near the Mexican subduction zone.

This wide variation in k_0 across rock sites indicates that the hardness of the surficial rocks might play a significant role in near-surface attenuation (Cranswick, 1988; Rebollar *et al.*, 1990) in addition to the rock type.

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