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SOURCE PARAMETERS OF SOME RECENT EARTHQUAKES IN GREECE BASED ON THEIR SPECTRAL CHARACTERISTICS.

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ABSTRACT

From digital recordings in the area of Greece, the seismotectonic source parameters of some recent earthquakes were estimated using P-wave displacement spectra of five stations and applying the Brune source model. For earthquakes of local magnitude 3.4 < M_L <4.9 the seismic moment varies between 0.9 and 4.3x10²³dyne-cm, the source radius between 1300 and 1900 m, the stress drop between 3.7 and 67 bars, and the average displacement on the fault plane between 1.5 and 22.0 cm.

ΣΥΝΟΨΗ

Στην εργασία αυτή υπολογίζονται οι χαρακτηριστικές παράμετροι σεισμικής εστίας σεισμών του Ελληνικού χώρου που έχουν καταγραφεί σε ψηφιακή μορφή από πέντε τηλεμετρικούς σταθμούς του Εθνικού Αστεροσκοπείου Αθηνών.

Για κάθε σεισμολογικό σταθμό υπολογίζεται το φάσμα μετατοπίσεων των P-κυμάτων, διορθωμένο ως προς την απόκριση του οργάνου και ως προς ένα μέσο συντελεστή που αντανακλά στον τρόπο διάδοσης της σεισμικής ακτινοβολίας από την εστία.

Από τα χαρακτηριστικά του φάσματος, το σταθερό πλάτος χαμηλών συχνοτήτων και την συχνότητα κορυφής, υπολογίζεται η σεισμική ροπή, η ακτίνα της ισοδύναμης κυκλικής σεισμικής πηγής, η πτώση τάσης και η μέση μετατόπιση στο επίπεδο του ρήγματος σύμφωνα με το μοντέλο Brune.

Από την ανάλυση προέκυψε ότι για σεισμούς του Ελληνικού χώρου με τοπικό μέγεθος από 3.4 εως 4.9, η σεισμική ροπή μεταβάλεται από 0.9 - 4.3x10²³dyne-cm, η ακτίνα της ισοδύναμης κυκλικής πηγής από 1300 εως 1900 μέτρα, η πτώση τάσης από 3.7 εως 67 bars, και η μέση μετατόπιση στο επίπεδο του ρήγματος από 1.5 εως 22.0 cm.

Εξ αιτίας του σχετικά μικρού αριθμού ψηφιοποιημένων σεισμών που αναλύθηκαν σ'αυτή την εργασία, δεν έγινε προσπάθεια υπολογισμού εμπειρικών σχέσεων μεταξύ των παραμέτρων της σεισμικής εστίας και του τοπικού μεγέθους.

ΛΑΤΟΥΣΑΚΗΣ Ι., ΣΤΑΥΡΑΚΑΚΗΣ Γ., ΔΡΑΚΑΤΟΣ Γ., ΠΑΠΑΝΑΣΤΑΣΙΟΥ Δ., ΔΡΑΚΟΠΟΥΛΟΣ. Παράμετροι σεισμικής εστίας με βάση τα φασματικά χαρακτηριστικά πρόσφατων σεισμών του Ελληνικού χώρου. Εθνικό Αστεροσκοπείο Αθηνών, Γεωδυναμικό Ινστιτούτο, 118 - 10 ΑΘΗΝΑ.

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1. INTRODUCTION

It is well accepted that the size of any earthquake is controlled by the effective stress on the fault plane, the strength of the fault material and the dimensions of the dislocation producting the seismic event.

It is also well known that the displacement spectrum of all earthquakes have some important characteristics. The low frequency constant amplitude is controlled by the integral of the final slip on the fault plane (AKI and RICHARDS, 1980). At higher frequencies, the amplitude decays linearly according to $f^{-\nu}$ with $\nu>1.5$ (HANKS and WYSS, 1972).

The corner frequency of a spectrum is determined by the intersection of the low-frequency level and the high-frequency asymptote. (BRUNE, 1970; 1971; SAVAGE, 1972; HANKS and WYSS, 1972; MADARIAGA, 1976). It is reciprocally related to the fault dimension L and is given by

$$f_o=K \cdot V/L \quad (1)$$

where V is the wave propagation velocity (V_p or V_s). The factor k strongly depends on the fault geometry and on the type of P or S wave used in the analysis. HANKS and WYSS (1972) and MADARIAGA (1977) proposed different models for rectangular or circular faults.

Brune's model considers that the slip and the slip rate are dependent on the stress, strength, radius and rupture velocity of the dislocation. In other words, this model assumes a constant stress at any point immediately before, and after the rupture.

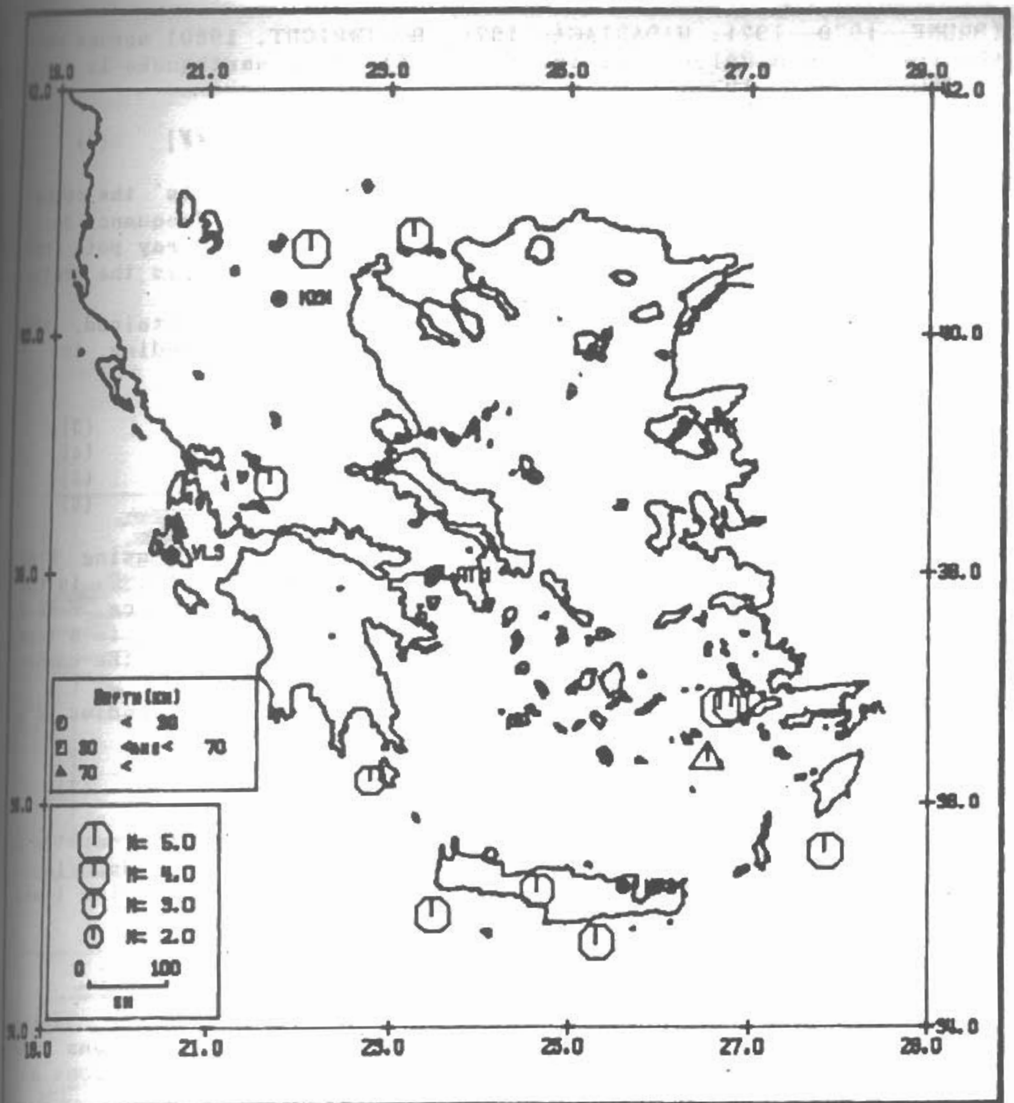
On the contrary, Madariaga's model considers that the difference between tectonic and frictional stress (effective stress) on the fault plane at any time is controlled by the preceding movement on the fault.

Both models have been applyied in different regions to obtain the source parameters such as seismic moment, stress drop, source dimension and radiated energy. In the most cases, the striking feature is the low stress drop which is obtained using the Brune's model (MODIANO and HATZFELD, 1982; STAVRAKAKIS et al; 1987) whereas the Madariaga's model reveals higher values.

The main purpose of this study is to determine the above mentioned source parameters by analysing digital recordings of some recent earthquakes occurred in different seismotectonic regions in Greece. The digital data are obtained from 5 telemetered stations of the National Observatory of Athens(fig. 1). Earthquake signals are detected by an automatic event detection system and recorded in digital form on magnetic tapes at the central station in Athens. Each signal is digitized at 50 sample/sec by a wide-range analog-to-digital converter in real time.

2. SOURCE PARAMETER ANALYSIS - SPECTRAL MODEL

The most common theoretical models of seismic sources



11 EVENTS
SCALE 1: 800000

Σχ.1.: Κατανομή των σεισμολογικών σταθμών και επικέντρων

Fig.1.:Distribition of digital stations and seismic events.

(BRUNE, 1970, 1971; MADARIAGA, 1976; BOATWRIGHT, 1980) assume that the far-field displacement spectrum V(f) of an earthquake is given by (BOATWRIGHT, 1978)

$$\log V(f) = \log \Omega_o - 0.43\pi fT/Q - 0.5\log[1-(f/f_c)^{2\gamma}] \quad (2)$$

where Ω_o is the low-frequency spectral level, f_c is the corner frequency, γ is a factor which determines the high frequency decay of the spectrum, Q is the quality factor along the ray path from the seismic source to the recording station, and T is the travel time.

Once the displacement spectrum has been obtained, the following source parameters can be determined according to Brune's model.

$$M_o(P,S) = 4\pi\rho V^3(P,S)\Omega_o(P,S)R/FR\vartheta\varphi(P,S) \quad (3)$$
$$r(P,S) = 2.34V(P,S)/2\pi f_o(P,S) \quad (4)$$
$$\Delta\sigma = 0.44 \;.\; M_o(P,S)/r^3(P,S) \quad (5)$$
$$u = Mo(P,S)/\pi\mu r^2(P,S) \quad (6)$$

where: $M_o(P,S)$ is the seismic moment as determined by using P or S waves, ρ, is density, V is the P- or S- wave velocity, Ω_o is the low-frequency constant level, R is the hypocenter distance, F is a term for correcting the free surface amplification, $R\vartheta\varphi$ is a term for correcting the average radiation pattern, fo is the corner frequency, and μ is the shear modulus.

If the Madariaga's model is applied, then the radius of a circular fault is given by

$$r = 0.32V_a/f_o(P) = 0.21\ V_a/f_o(S) \quad (7)$$

Assuming $f_o(P)/f_o(S)$ is 1.5, then Brune's model computes a radius 1.7 times greater than that calculated by Maderiaga. Therefore, the former model gives a stress drop that is five times lower than that of the later model.

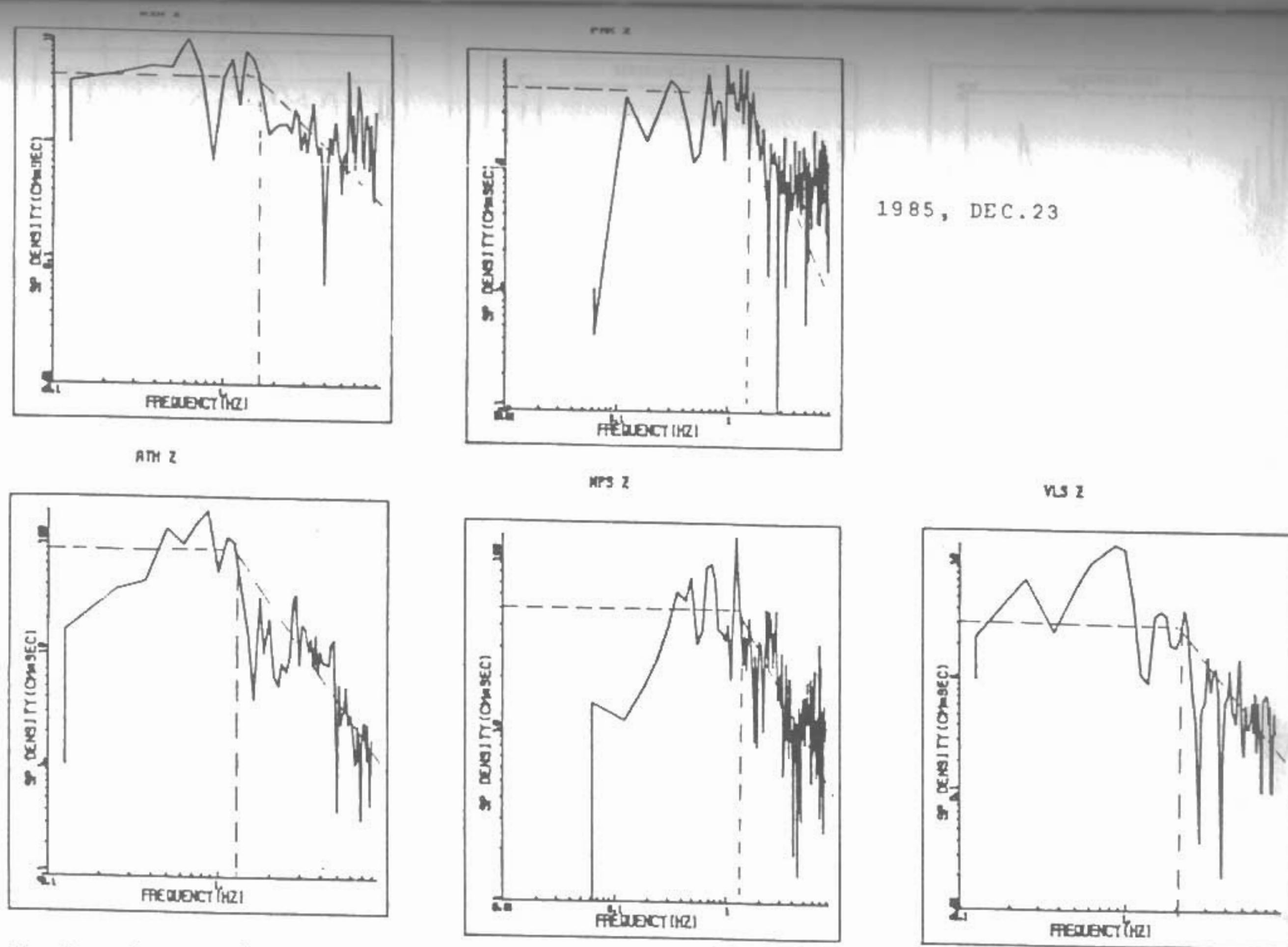
3. DATA ANALYSIS

Eleven earthquakes (Table I) recorded in the time period Dec.23, 1985-Feb.21, 1986 by at least 4 digital stations have been analysed. The locations of the seismological stations and seismic events are shown in Figure 1.

They have been selected on the basis of the number and quality of the records plus a good distribution over the area of Greece.

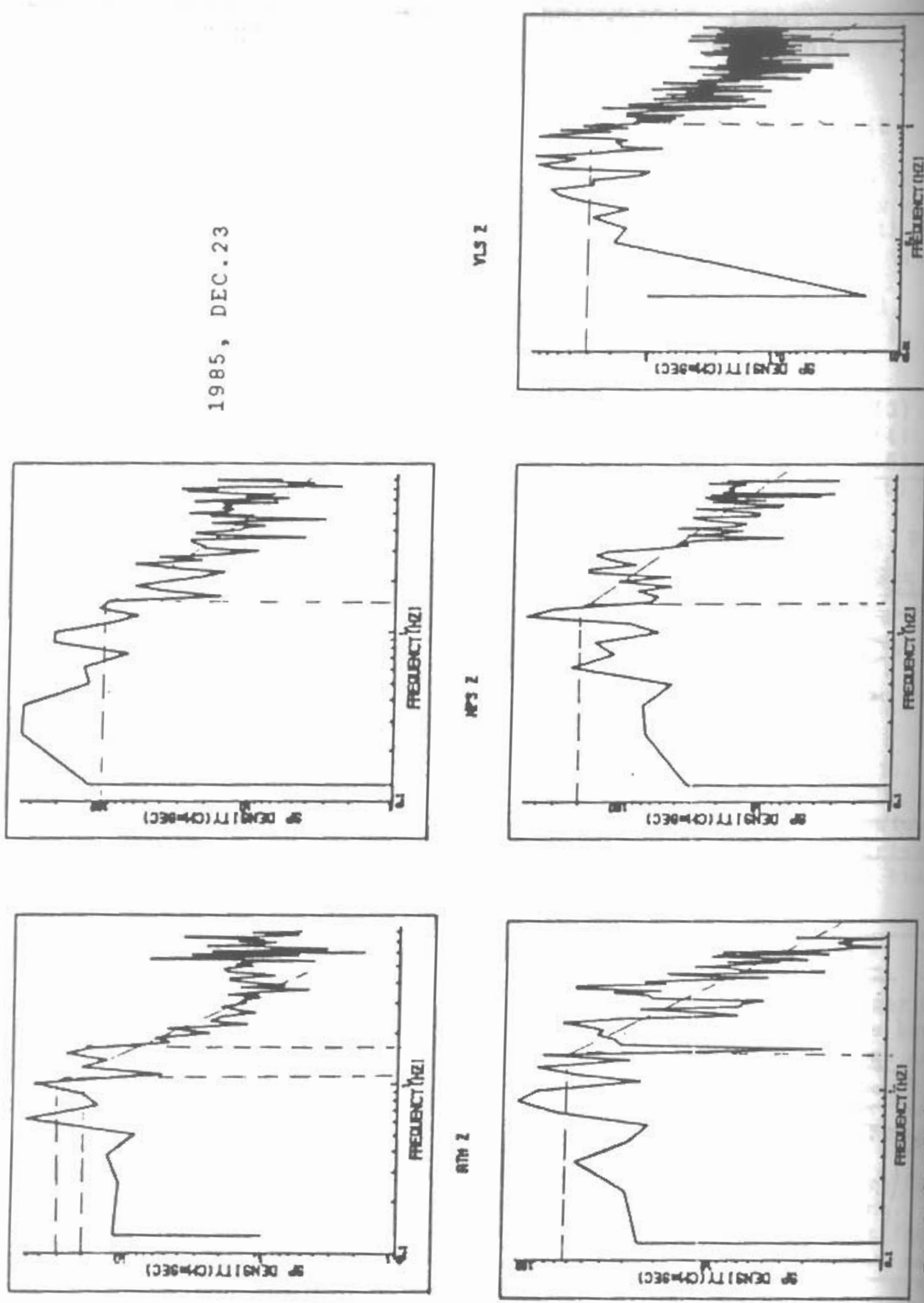
Only P-waves digital data has been used. The spectra for each seismological station were computed using a FFT-routine. A deconvolution procedure was also applyied to correct the obtained spectra for the instrument response. The shape of the spectra has been examined by taking different signal duration. In the most cases, the time duration was the first 3 to 5 sec of the P-wave train. Figure 2 illustrates the corrected spectra for each seismic event of the Table I and for each seismological station.

Using a P wave velocity V_p=6.0 km/sec for the source material

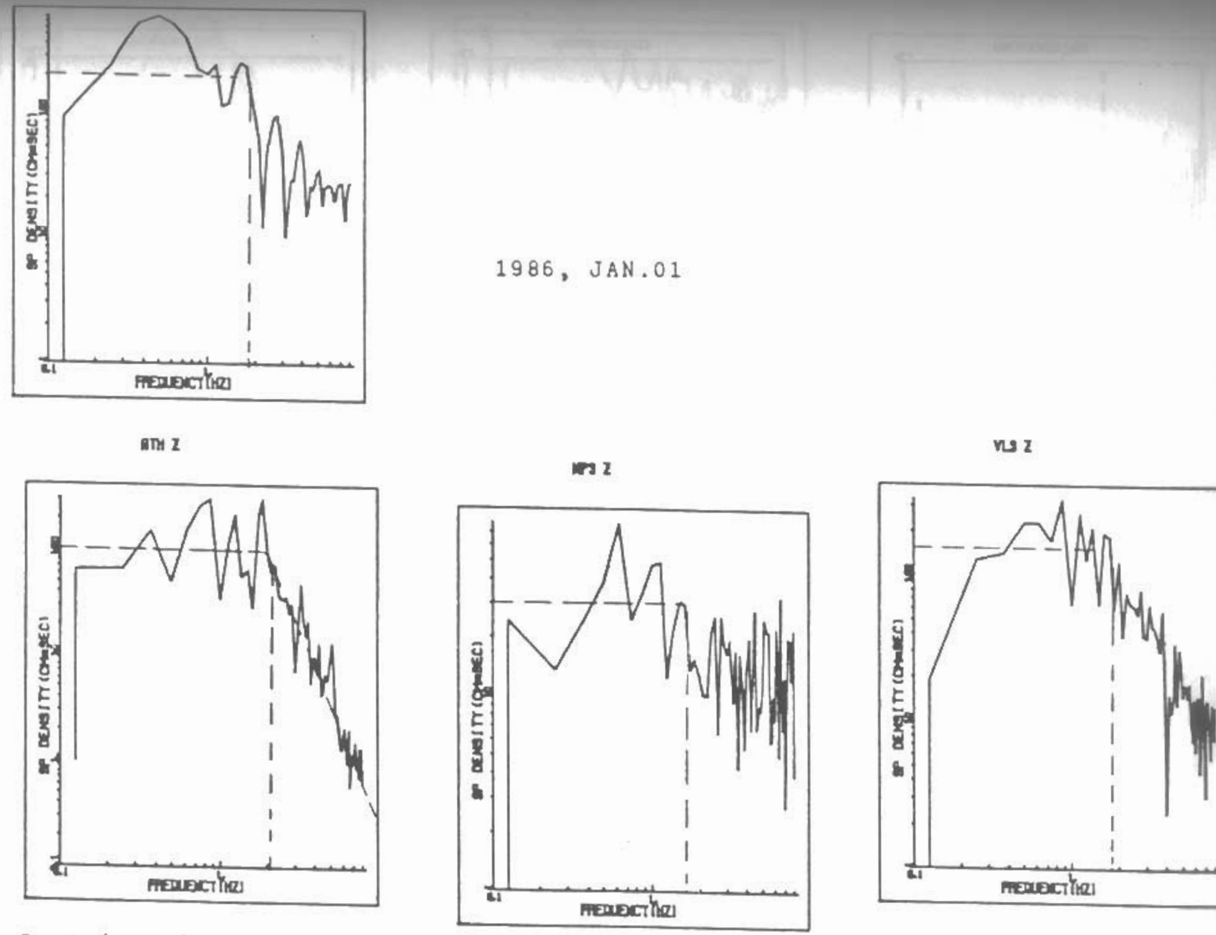


Σχ.2.: Διορθωμένα Φάσματα

Fig.2.: Correeted spectra



Σχ.2.(συν.)
Fig.2.(cont.)



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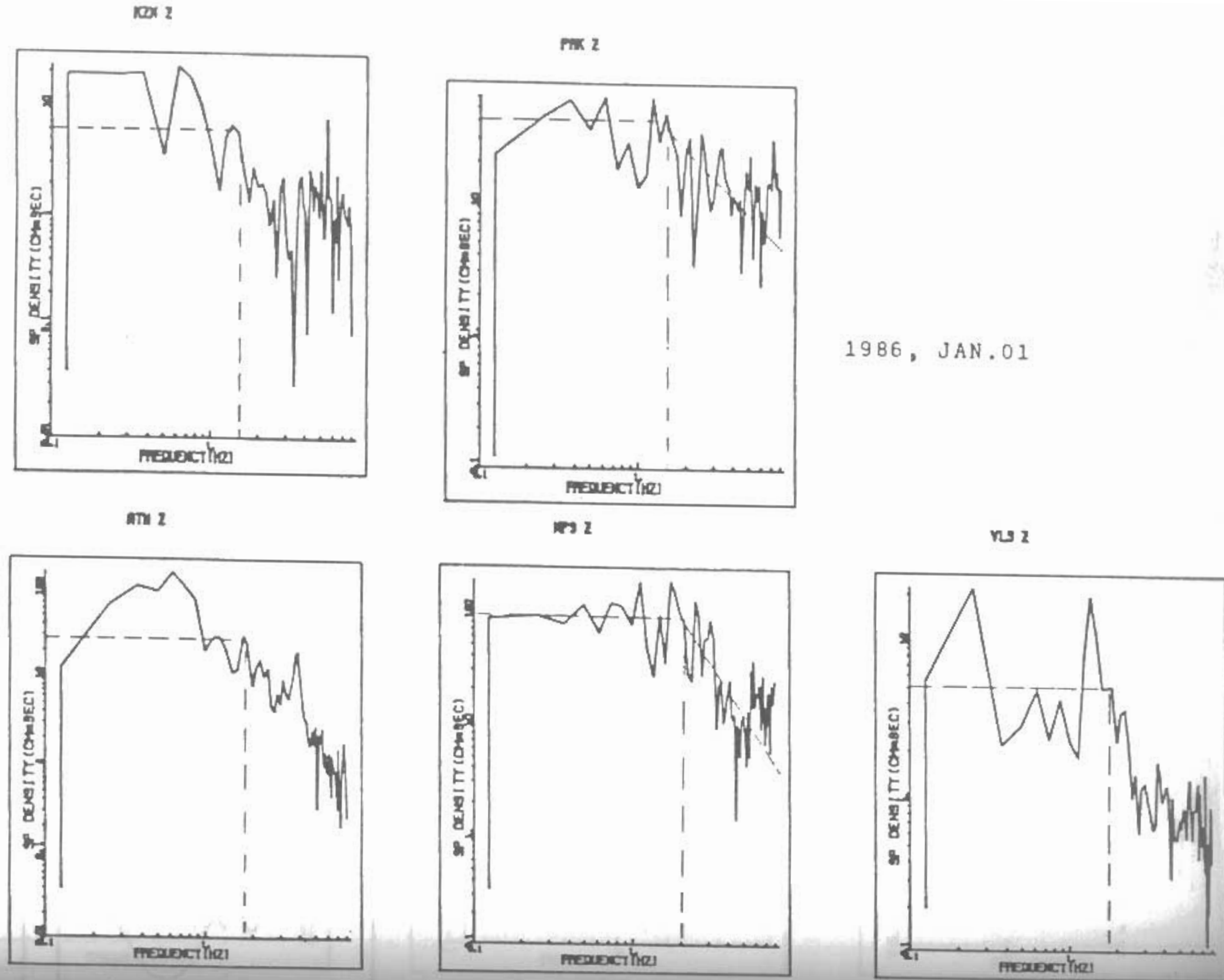

Σχ.2.(συν.)

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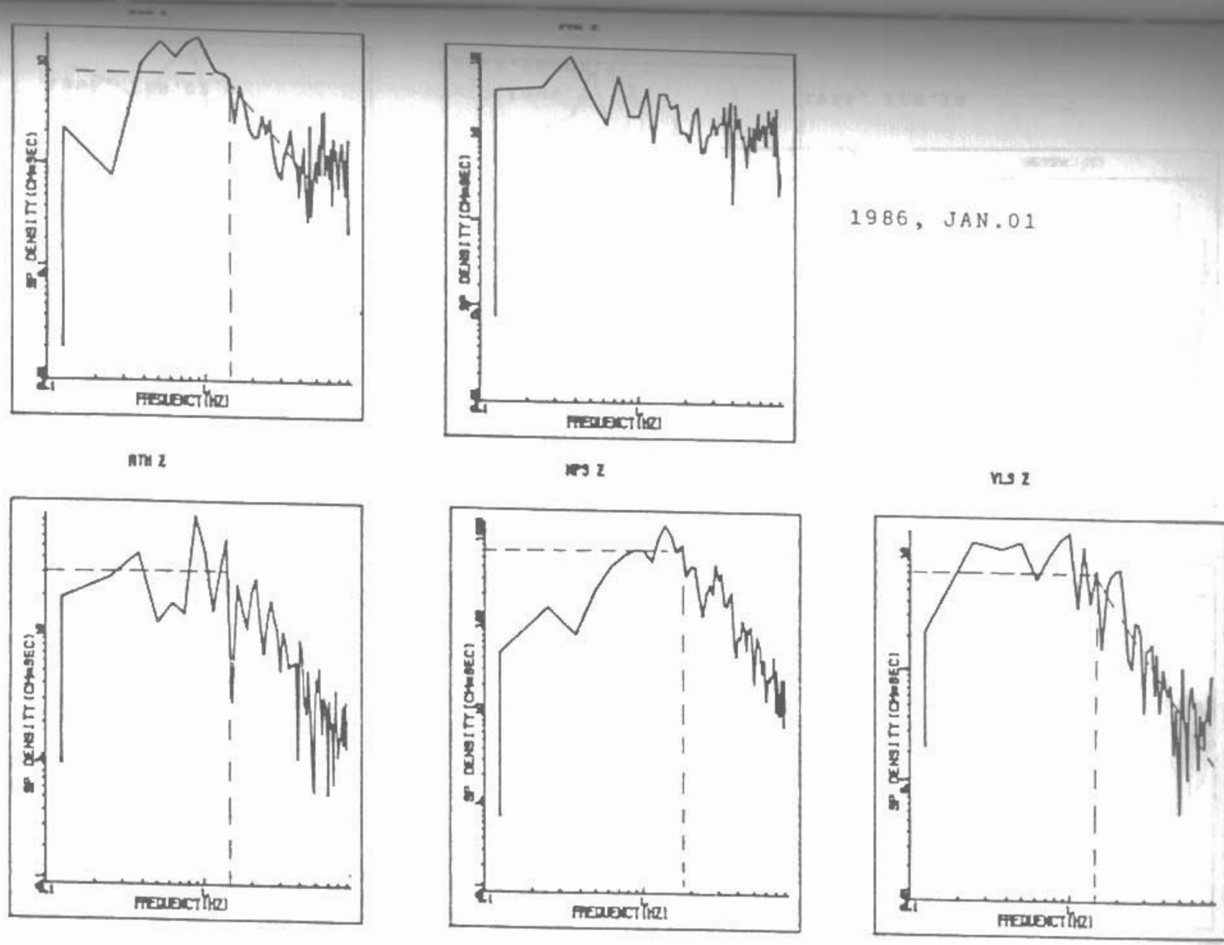
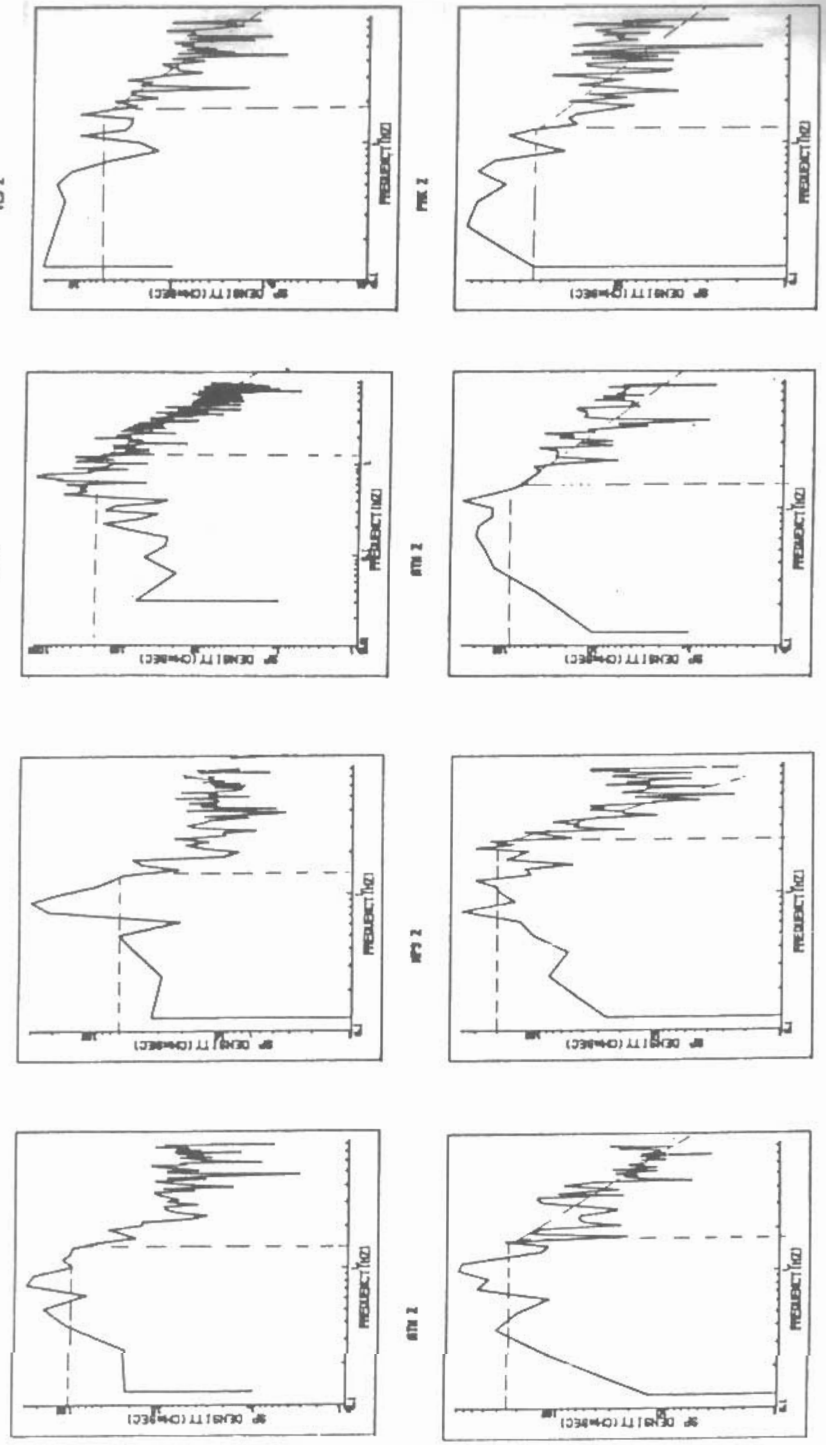


Σχ.2.(συν.)
Fig.2.(cont.)



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Σχ.2.(συν.)

Fig.2.(cont.)

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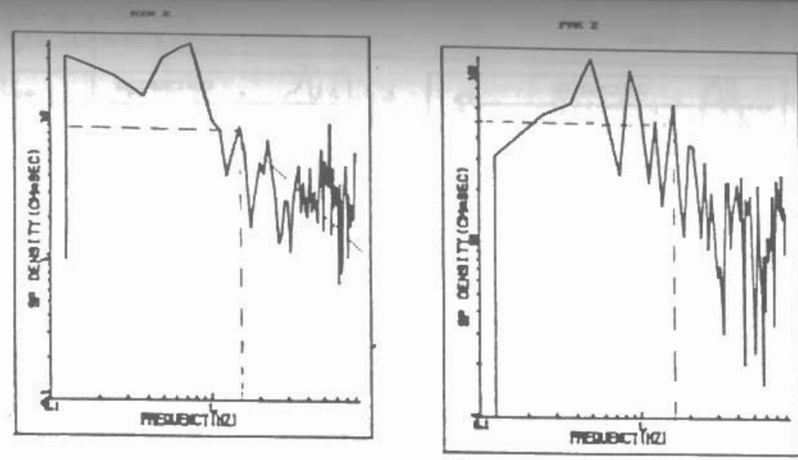
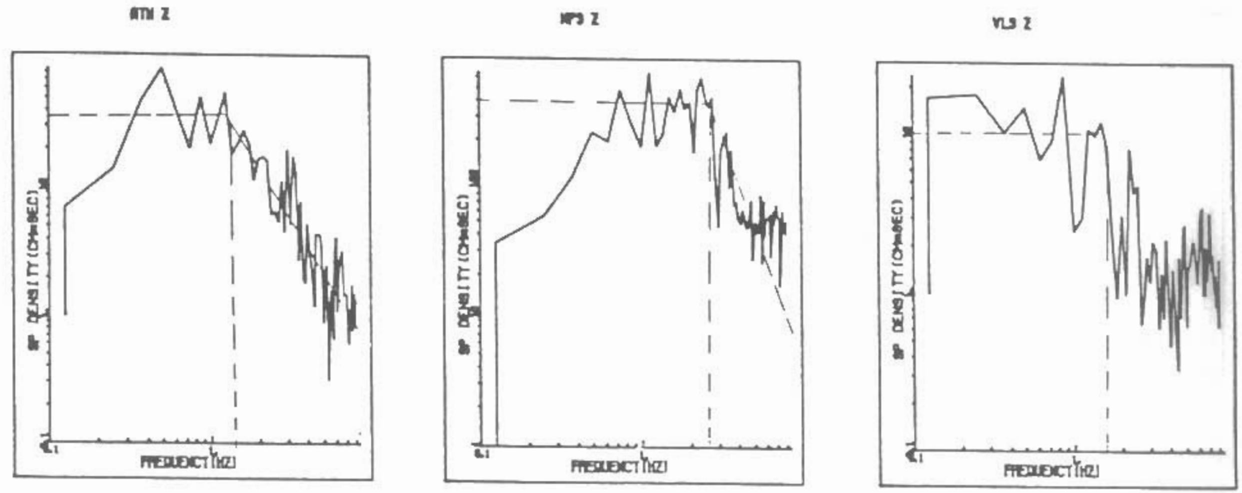
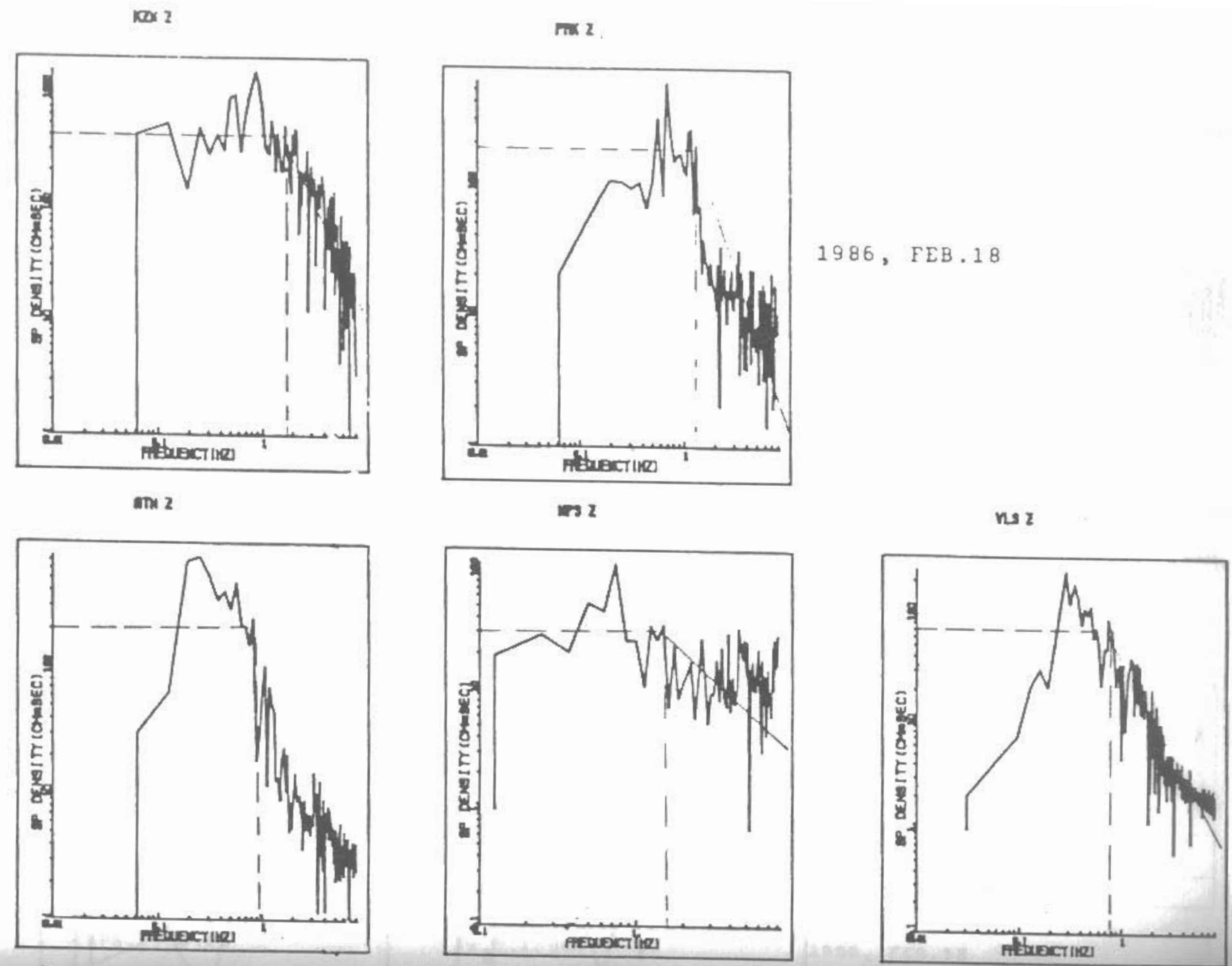


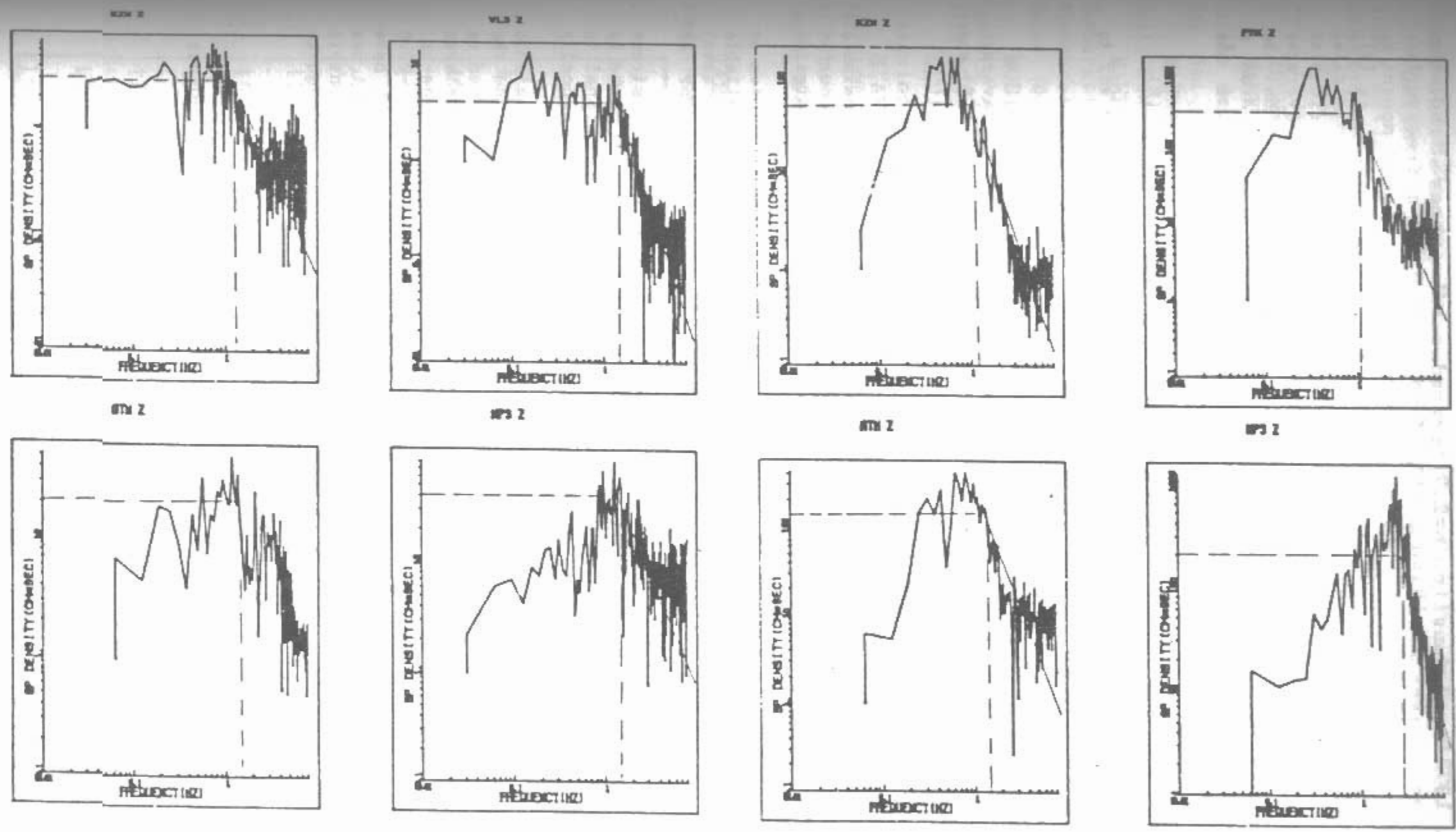


Σχ.2.(συν.)

Fig.2 (cont.)



Σχ.2.(συν.)
Fig.2.(cont.)



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1986, FEB.21

Σχ.2.(συν.)

Fig.2.(cont.)

(MAKRIS, 1977), a density $\rho=2.7$ gr/cm^3, an average radiation pattern for P waves $R\theta\varphi(P)=0.6$ (FLECTHER, 1980) and a free surface reflection coefficient F=0.5, we determined the seismic moment M_o and the radius of the circular source by using eq.(3) and eq.(4), respectively for each earthquake recorded at the five digital stations. The final seismic moment was taken as a geometric mean of each station, since a simple arithmetic mean produces averages biased to the higher values. This is due to the fact that the errors associated with the interpretation of Ω_o and f_o on a log-log plot are longnormally distributed. To equalize the errors, the geometric mean is taken as

$$\log\langle M_o\rangle = 1/5 \;.\; \Sigma \log M_{oi} \qquad (8)$$

The mean radius of a circular fault is found in a similar way to the seismic moment,

$$\log\langle r\rangle = 1/5\ \Sigma \log r_i \qquad (9)$$

Finally, the mean stress dop $\langle\Delta\sigma\rangle$ and the average displacement on the fault plane are computed by using eq. (5) and eq (6), respectively. The results are summarized in Table I.

4.DISCUSSION AND CONCLUSIONS

The main purpose of this study is to obtain the seismic source parameters of some small to moderate earthquakes occurred in different seismotectonic regions in Greece by using digital waveforms.

By analysing these data, the P-wave displacement spectra at each seismological station have been computed. To obtain reliable estimates of the low-frequency constant level, the displacement spectra were corrected for the instrument response and for an average radiation pattern of P-waves.

The source parameters, seismic moment, source radius, stress drop and average displacement on the fault plane were computed by assuming that the low-frequency constant level is proportional to the seismic moment and the corner frequency reciprocally proportional to the source radius.

The lowest stress bar of 3.7 bars is obtained for the seismic event of $M_L=3.4$ occurred on Feb.20,1985 (36.19°N-22.79°E) and the highest (67 bars) for the seismic event of $M_L=4.3$, occurred on Feb.2, 1986 (35.0°N-23.49°E) The source radius varies between 1300 and 1900 m, the seismic moment between 0.4-4.3x10^{25}dyne-cm, and the average displacement on the fault plane between 1.5 -22.0 cm. Due to the relative small number of earthquakes, which have been digital recorded at least at four stations, no attempt has been made in this study to establish an empirical relationship between the obtained source parameters and the local earthquake magnitude.

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TABLE I: Earthquake data and spectral characteristics for some recent earthquakes digital recorded in the area of Greece.

DATE Y M D	M_L	D km	LAT °N	LONG °E	M_0 $x10^{23}$ dyne.cm	⟨r⟩ m	Δσ bar	⟨u⟩ cm
1985, Dec.23	4.2	5	36.85 -	26.81	0.8	1471	11	3.9
1985, Dec.23	4.9	5	36.82 -	26.69	1.6	1731	13	5.7
1986, Jan.01	3.9	26	38.76 -	21.69	1.9	1307	33	10.
1986, Jan.01	4.2	25	34.75 -	25.31	3.2	1536	38	14.
1986, Jan.01	4.5	21	35.57 -	27.84	0.9	1376	15	5.
1986, Feb.02	4.3	29	35.00 -	23.49	4.2	1408	67	22.
1986, Feb.15	4.1	5	35.22 -	24.65	1.2	1382	20	6.7
1986, Feb.18	4.1	5	40.81 -	23.26	1.3	1601	14	5.4
1986, Feb.18	4.6	5	40.70 -	22.13	3.2	1961	20	9.4
1986, Feb.20	3.4	5	36.19 -	22.79	0.4	1614	3.	1.5
1986, Feb.21	4.4	127	36.37 -	26.54	4.3	1828	46	17.