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MAPPING OF CODA ATTENUATION AT THE EXTEND OF THE NATIONAL SEISMOLOGICAL NETWORK OF GREECE

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ABSTRACT

Coda decay rates of 538 vertical components corresponding to local earthquakes which occurred in Greece during the period 1998 to 1999 were used to deduce the coda quality factor (Q_c) characteristics in the Hellenic area. The seismograms have been selected from a broader sample of 776 records obtained at 8 stations of the National Seismographic Network operated by the Institute of Geodynamics of the National Observatory of Athens. Earthquake magnitudes range from 2.5 to 4.0; epicentral distances and depths are smaller than 100 km and 40 km, respectively. Using the Single Back Scattering model, the dependence of Q_c on frequencies between 1 and 10 Hz has been investigated at each station and the usual $Q_c = Q_0 f^n$ relationships have been deduced. The spatial distribution of Q_0 has been drawn using waves that sample approximately equivalent ellipsoidal volumes with semiminor axis up to 100 km. The corresponding map shows a decreasing trend in S-N direction.

1 INTRODUCTION

In spite of their theoretical limitations, the analysis of waves of coda has been considered an effective method to estimate quality factor of seismic wave attenuation. Nevertheless, the influence of some analysis parameters like length of the time window and selection of the beginning of coda, affects the results.

In this sense obtained values are not easy to compare even within the same territory.

Besides that, results for most of territories concerns limited extent of areas or lack of uniform seismological data. To overcome such a difficulty, the spatial distribution of Q in an extensive zone can be obtained by applying the same methodology to a uniform set of data in the extent of dense national seismological network.

Modern instrumentation offers the possibility to analyze the spatial distribution of Qc (Q factor considered from waves coda) in the Greek territory, area for which numerous studies exists (see APPENDIX table, from Panagiotopoulos et al., 1998., competed by the authors) but, nevertheless, in zones of small size, usually covered from locally operating seismological networks, for which the temporarily character doesn't permit any future comparison. (Martin, 1988, Tselentis et., al., 1988, Baskoutas et., al., 1989 ; 1992 ; 1993; 1995; Hatzidimitriou, 1993; 1995; Baskoutas, 1996; 1998; Tselentis, 1997).

Single Back-Scattering model has been chosen to be used in the present study because it facilitates the comparison with other studies made in different zones within Greek territory and elsewhere.

In order to obtain the spatial distribution of Qc values, data with good azimuthal distribution are selected to cover homogeneously the space around the seismological stations.

Tests have been made by running both the CODAQ Havskov's (1989) and Baskoutas software (1993) as well as the Single Isotropic scattering model (Sato, 1977a,b) at a representative set of data. No significant differences have been noticed.

2 DATA

We used 538 earthquakes which occurred in the period 1998 to 1999 and were recorded by eight seismological stations of the National Seismic Network of Greece.

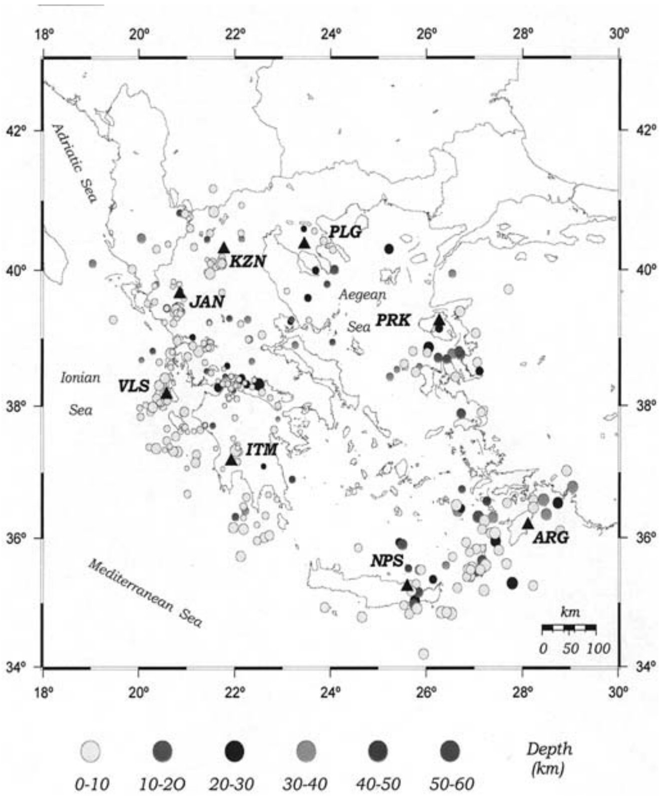

Figure 1 Epicenters map (The locations of the stations is shown by triangles).

A first set of 776 earthquakes were obtained from vertical components at eight stations of the National Seismic Network of Greece. Magnitudes are between 2,5 and 4,0. Hypocenter depths and epicenter distances are less than 40 km and 100 km respectively (Figure 1). All events were recorded by broadband seismometers of three components. In both cases the sampling frequency is 50 sample/sec. Seismograms were inspected visually for errors (i.e. noise contamination and location parameters). Therefore some of them have been rejected and a total of 538 events have been selected (Table 1).

Table 1. Stations and number of events.

Station Name	Nº of Events
ARG	55
ITM	74
JAN	53
JAN	63
KZN	45
PLG	51
PRK	79
VLS	118

The noise level was evaluated considering the average value of the spectrum amplitude corresponding to 10 second before the arrival time of P- wave. S wave arrival was identified on the horizontal components.

3 ANALYSIS AND RESULTS

As a first step we studied at each station, the variation of Q value for six different parameter sets resulting from combinations between chosen time window and coda onsets i.e. considering three different length of time window (10, 20 and 30s) and two coda waves origin time (t = 1.5ts and t = 2ts). The analysis was carried out using the model of Single Back-Scattering (Aki and Chouet, 1975). Signals are filtered by the mean of band-pass filter with center frequencies at 1.5, 3, 5, 7 and 9 Hz. Analysis has shown that the most stable results were obtained, using as coda wave origin time the value of 2ts and a length of lapse time window 20 sec. (Perez, 2000). Table 2 shows the results for Q_0 for entire coda length (value of Q_c at 1 Hz) and n corresponding to the power low relation for each station.

$Q_c = Q_0 f^n$ (1)

For Q_0 the spatial distribution of the common sampling volumes for each event was considered. This volume depends on the lapse time interval t. In this way scatterers that take part in the process of coda waves generation, are located, in a volume of an expanding elipsoid, with foci the station and the source (Pulli, 1984).

$$\frac{x^2}{(v_s t/2)^2} + \frac{y^2}{(v_s t/2)^2 - R^2/4} = 1 \qquad (2)$$

In the relation (2) Vs is the shear wave velocity, t is the travel time interval and R is the source-station distance. The semiaxis a_1 and a_2 are equal to $(v_s t/2)^2$ and a_1^2 - $R^2/4$ respectively.

Examined ellipsoids can be practically considered spherical ($a_1/a_2 \approx 1$) thus maximum depth can be defined as $z_{max}=a_2+$ h, where h is the depth of the earthquake (Havskov et., al., 1989). S wave velocities with respect to the depth are considered as follow:

$h \leq 15$ km $\Rightarrow$ $v_s = 3.47$ km/s
$15 < h \leq 40$ km $\Rightarrow$ $v_s = 3.90$ km/s,

which correspond to the regional velocity model, used by the Geodynamic Institute of National Observatory of Athens, for the earthquake location.

For the analysis two restrictions were adopted. First, the dimension of the sampling volume, which should mostly correspond to the crust and second, having at the same time a sufficient number of events to be processed, which guarantees for the results significance. The optimal value between these two conditions was $a_2 \leq$ 100km. Although the number of earthquakes for each station (values between parenthesis in Table 3) in some cases, was reduced drastically, still it can be considered sufficient for the study. Figures 2 and 3 shows Qo and n values, for different ellipsoid semi axis values (100, 130, 160Km) at each station of the Seismological network. Open circles stand for a_2 =100Km, full rectangles and triangles for 130 and 160Km, respectively. The clear difference of Q_o values among the group of stations situated in the concave part of the island arc (JAN KZN, PLG, PRK), and those situated in the convex part (ARG, ITM, NPSM and VLS), can bee seen in figure 2.

Table 2. Q_o and **n** values

Station	Q_o	n
ARG	83±1	0.89±8e2
ITM	99±8	0.63±5e-2
JAN	67±4	0.71±5e-2
KZN	67±9	0.63±9e-2
NPS	76±2	0.89±2e-2
PLG	71±5	0.73±6e-2
PRK	91±8	0.80±6e-2
VLS	78±2	0.82±2e-2

Table 3. Q_o and n values for different values of a_2 parameter

Station	Q_o	n	No of cases	Q_o	n	No of cases	Q_o	n	No of cases
	($a_2 \leq$100 km)			($a_2 \leq$130 km)			($a_2 \leq$160 km)		
ARG	77±12	0.84±7E-2	(4)	77±6	0.89±6E-2	(21)	71±5	0.945±1E-3	(41)
ITM	71±10	0.644±1E-3	(9)	83±7	0.64±7E-2	(24)	92±7	0.63±4E-2	(48)
JAN	59±3	0.71±5E-2	(31)	59±3	0.75±5E-2	(42)	63±4	0.74±5E-2	(47)
KZN	59±7	0.68±7E-2	(19)	59±7	0.68±7E-2	(21)	63±8	0.67±8E-2	(34)
NPS	69±4	0.77±3E-2	(12)	71±5	0.87±5E-2	(23)	72±3	0.90±3E-2	(36)
PLG	60±2	0.77±2E-2	(14)	63±1	0.760±9E-3	(25)	71±5	0.74±5E-2	(38)
PRK	59±7	0.91±8E-2	(12)	82±5	0.81±4E-2	(31)	87±6	0.79±4E-2	(42)
VLS	76±3	0.68±2E-2	(21)	76±2	0.78±1E-2	(42)	79±3	0.79±2E-2	(75)

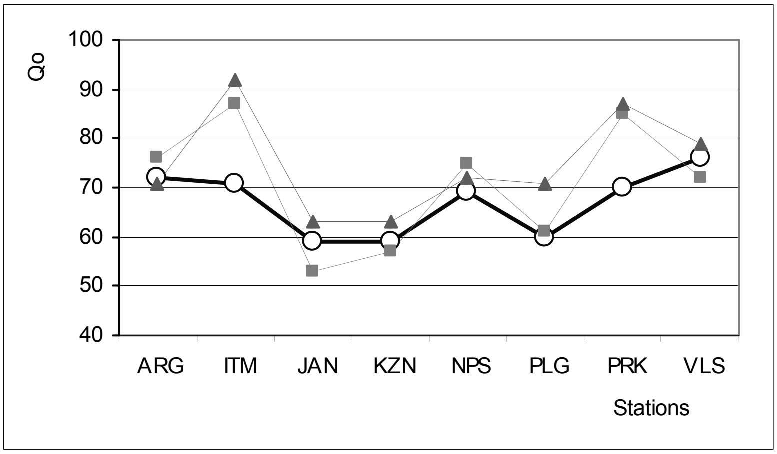

Figure 2. Qo at the NOA seismic stations for different ellipsoid semi axis values (a_2 =100Km, open circles). Full rectangles and triangles represents the Qo values for a_2 equal to 130 and 160Km respectively.

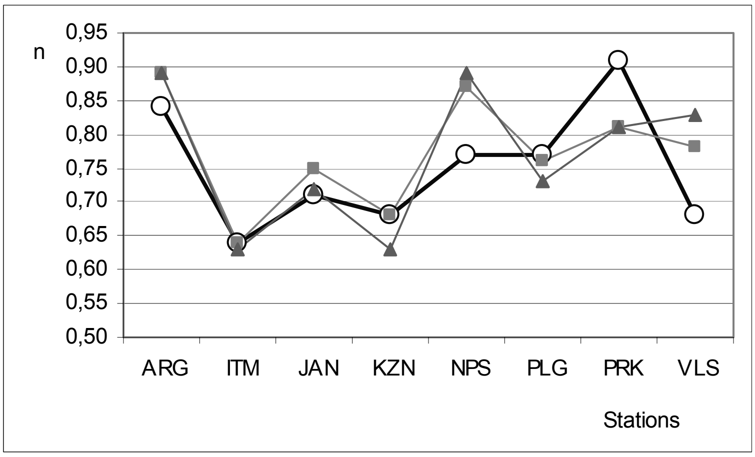

Figure 3. n values at the NOA seismic station for different ellipsoid semi axis values, (a_2 =100Km, open circles) . Full rectangles and triangles represents the Qo values for a_2 equal to 130 and 160Km respectively.

4 DISCUSSION AND CONCLUSIONS

The obtained results show that the Hellenic region is characterized by a high seismic attenuation. Q values of the table 2, summarizes the data obtained for all earthquakes in each station without considering any restrictions for the sampling volume. These results are, in general, coherent with those obtained in previous studies, when the comparison is possible. Thus, Hatzidimitriou (1993), using a time window of 15-30s, has obtained, for north Greece, Q_o = 60 and n = 0,79 that is very similar to the results of this work for PLG station. The similarity increases when a_2= 100 Km is considered.

In the case of Kozani station also coherence exists, within the margin of error, with the results of Baskoutas et., al., (1998) for the window of 20s. Instead, for Peloponnesus area and for unknown length of time window, Martín (1988) reports Q_o = 73 and n = 0,79, that differs from the results of this work at ITM station, located in the western part of the zone. In several cases comparison with results of other authors is not easy, because of missing information or of different parameters set used for the data analysis.

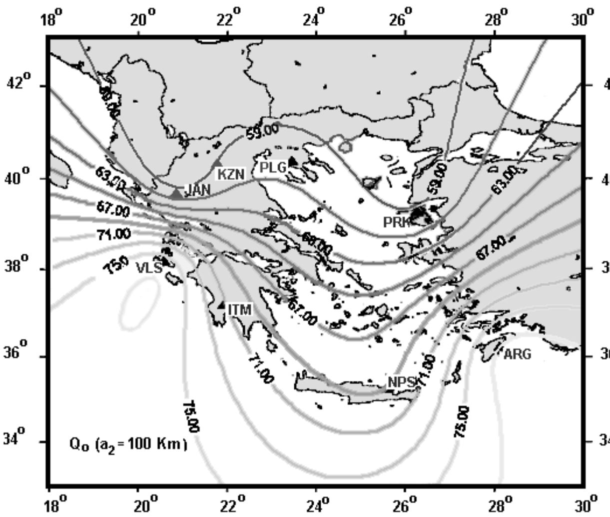

Figure 5. Spatial distribution of Qo for $a_2 \leq 100$ km

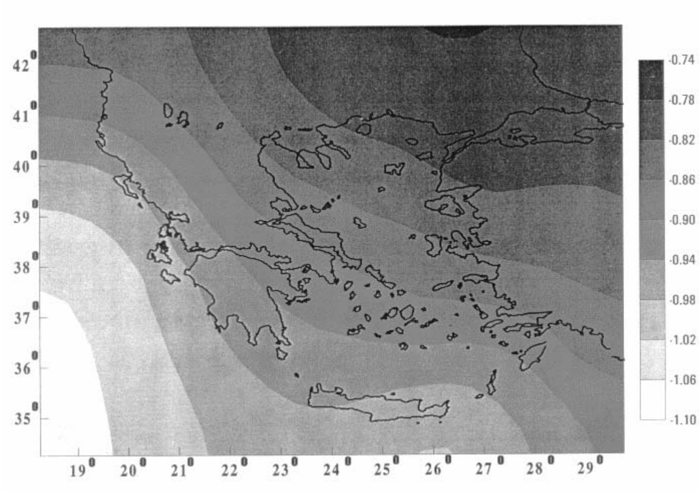

Figure 6. Spatial variation of b value from superficial seismic activity, (Papazachos and Papazachou 1997).

Obtained spatial variation for $a_2 \leq 100$ km (Figure 5) shows a significant attenuation characteristic for Greek terittory, and indicates that attenuation in the concave zone is larger that in the convex one.

In figure 5, also, a sharp Qo variation in the Ioanian Sea islands is observed with a slight increase towards the N-S direction. This area is characterized by high seismic activity and is influenced by different tectonic regimes. It is also important to notice that this tendency keeps a remarkable similarity with the spatial variation (Figure 6) of b value given by Papazachos and Papazachou (1997) for shallow seismic activity. Tendency indicating that b value decrease in a systematic way from the southwest to the northeast. This result indicates that the values of Q_c tend to diminish in the zones in which the geological formation age is older (Baskoutas et al., 2000).

All the values assigned to the semiaxis a_2 imply that the sampling volume comprises also part of the upper mantle playing an important role to the increase of Q_c values, the contribution of the crust must be very small. In order to confirm the above statement, it is necessary to diminish axis a_2 (and thus the upper mantle contribution) using higher number of events.

Although the differences are small, the comparison of the results obtained for different values of the sampling volume (Table 3) confirms the increase of Q_o as depth increases.

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APPENDIX

Table of Qc power low estimates in the territory Greek.

Lapse time or distance	$Q_c = Q_o f^n$	Region	Reference
10-20 sec	$Q_c=33f^{1.01}$	North Greece	1
15-30 sec	$Q_c=60f^{0.79}$	"	"
20-45 sec	$Q_c=89f^{0.72}$	"	"
30-60 sec	$Q_c=94f^{0.78}$	"	"
50-100sec	$Q_c=128f^{0.74}$	"	"
20 sec	$Q_c=47f^{1.02}$	Kozani-Grevena	2
40 sec	$Q_c=80f^{0.87}$	"	"
60 sec	$Q_c=100f^{0.78}$	"	"
80 sec	$Q_c=124f^{0.70}$	"	"
100 sec	$Q_c=140f^{0.71}$	"	"
10 sec	$Q_c=29f^{0.91}$	Central Greece	3
20 sec	$Q_c=45f^{0.85}$	"	"
30 sec	$Q_c=62f^{0.83}$	"	"
40 sec	$Q_c=80f^{0.80}$	"	"
50 sec	$Q_c=101f^{0.73}$	"	"
-	$Q_{f=1Hz}=182$	Athens	4
-	$Q_c=73f^{0.95}$	Peloponnesus	5
30 sec	$Q_c=121f^{0.72}$	Gulf of Patras	6
50 sec	$Q_c=141f^{0.75}$	"	"
70 sec	$Q_c=144f^{0.81}$	"	"
90 sec	$Q_c=162f^{0.83}$	"	"
10-20 sec	$Q_c=16f^{1.1}$	West part of Korinth Gulf	7
-	$Q_{c(f=4Hz)}=183$	Aegion	8
-	$Q_{c(f=8Hz)}=270$	"	"
-	$Q_c=43f^{0.81}$	Kalamata	9
0-450Km	$Q_{f=1Hz}=350$	Aegean sea	10
30-250 Km	$Q_{f=8Hz}=200\text{-}300$	NA part of Hellenic arc	11

(1) Hatzidimitriou, 1993, (2) Baskoutas et al., 1998, (3)Baskoutas, 1996, (4) Baskoutas et. al. 1992, (5) Martin 1988, (6) Tselentis 1993b, (7) Baskoutas etal., 1994, (8) Tselentis, 1997, (9) Tselentis et al., 1988b, (10) Papazachos C, 1992, (11) Kovachev *et al.,* 1991.