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STUDY OF CODA Q IN EL SALVADOR

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ABSTRACT

Shallow crustal coda Q under the volcanic belt in El Salvador was determined as a function of frequency in the range 1-16 Hz, using 553 microearthquakes with focal depths between 0-20 kms.

The model developed by Aki and Chouet for the coda wave generation and propagation was used. The analysis was made for different groups of data. An average of all data results in a Q relationship of $Q = 52f^{0.78}$, where f is the frequency.

Coda Q was determined as a function of lapse time. In contrast to studies worldwide little variation with lapse time was found, indicating that coda Q has little variation with depth. Very little regional variation in coda Q was found. Only a coda Q around a geothermal field showed a slightly higher Q than the regional average. This study illustrates that the separate local coda Q differences can be resolved when very local data is available.

INTRODUCTION

Coda Q is used extensively to characterize crustal attenuation and several studies have already been done in Central America (Martínez, 1994; Ligorría, 1995). Most studies have been on a regional scale and there are no local coda Q results published.

Considering the variation in the tectonic features in the region, there seem to be little variation in reported coda Q (Ligorría, 1995). However, results might be difficult to compare due to variation in lapse time (Martínez, 1994; Ligorría, 1995) which is often not reported.

The purpose of this study is to find a crustal zonation of the coda Q using the local microseismicity recorded in El Salvador for the areas along the volcanic chain. The volcanic chain is a major geological feature of the convergent plate boundary formed by northeastward underthrusting of the Cocos Plate beneath the Caribbean plate along the Middle America Trench (Harlow et al., 1993). Seismicity associated with the volcanic chain is generally confined to the upper 20 km of the crust and within a nearly continuous belt of 20 km width along the axis of the principal Quaternary volcanoes (Bommer, 1996). The availability of short period seismograph stations, in the area makes it possible to record the microseismicity generated either by local fault movements or volcanic activity.

There are two seismic networks (Figure 1). One is operated for CIG (Centro de Investigaciones Geotécnicas) and the other for CEL (Comisión Ejecutiva Hidroeléctrica del Río Lempa). The CEL network is located in the Berlin geothermal field, with 9 short period stations, and has been working since February 1996. The CIG network has stations in the whole country but the majority are concentrated in and around San Salvador city. It started to operate in 1983 with 10 stations, in the end of 1991, 11 more stations were installed but there are now 11 stations in operation (Torres, 1998).

THE CODA Q METHOD

Coda waves compose the latter part of the seismogram of a local event. The method was introduced by Aki and Chouet (1975) and Rautian and Khalturin (1978), who found that the seismic band pass filtered wave envelope decay with time in a fashion related to Q.

Aki (1969) and Aki and Chouet (1975) concluded that the seismic coda waves of local earthquakes are backscattering waves from numerous randomly distributed heterogeneities in the earth. Aki and Chouet (1975) consider two specific models to explain the coda wave origin. One is the single-scattering model. In this the scattering is considered to be a weak process, and the loss of seismic energy by scattering is neglected. The other is the diffusion model, where the seismic energy transfer is considered as a diffusion process.

Q determined from coda waves is generally found to be a function of frequency of the form.

$$Q = Q_0 f^{\alpha} \qquad (1)$$

Both α and Q_0 show regional variation, often related to tectonic features (Biswas and Aki, 1984 ; Havskov et al., 1986).

Assuming single scattering from randomly distributed heterogeneities, Aki and Chouet (1975) have shown that the coda wave amplitude at frequency, f, and elapsed time, **t**, from the origin can be expressed as

$$A(f, t) = c*t^{-a}*e^{-(\pi f*t/Q)} \qquad (2)$$

where **c** is the coda source factor, **a** the geometrical spreading factor (1, 0.5 , and 0.75 for body wave scattering, surface wave scattering, and diffusion, respectively) and Q is the quality factor.

Equation (2) can be logarithmicaly expressed as

$$\ln (A(f, t)) + a\ln (t) = \ln (c) - \pi f t/Q \qquad (3)$$

Hence Q at frequency f can be determined from the slope of the ln $(A(f, t)*t^{a})$ versus time distribution.

DATA SELECTION AND ANALYSIS

The data set consists of 553 earthquakes, where 325 recorded by CIG stations, 166 recorded by CEL stations and 62 recorded by both CEL and CIG stations. The events selected for this study are from 07/1996 to 06/1997 for CEL and from 01/1993 to 08/1997 for CIG. Figure 1 shows the epicenters of this data set. The criteria for the selection were a good signal to noise ratio and focal depth between 0-20 km.

For the purpose of studying 3 dimensional variation in Q, the data was separated into 5 groups.

1) CIG: Epicenters recorded on CIG stations. This is to sample the western part of the area.

2) COM (CEL+CIG): Epicenters located between CIG and CEL and recorded by both networks. This is to study the central part of the area.

3) CEL only recorded on CEL. This is to study the eastern part.

4) Ilopango lake, only shallow events (depth 0-5 km) . This has the purpose to study the shallow part of the crust in the central section.

5) CEL, only shallow events near the network with focal depths between 0 and 5 km. This is to study the shallow part of the crust near CEL.

On Figure 1 the main areas sampled by the 5 data sets are shown. As it can be seen, there is substantial overlap. However, groups 4 and 5 have no overlap at all and if any lateral variation is to be observed, group 4 and 5 should give an indication. The other purpose of separation of results from group 1 and 4, and 3 and 5 is to study the variation of Q with depth. Finally, coda q is also calculated for the whole data base together in order to have a regional value for reference.

Coda Q is calculated following Havskov et al. (1989). The program is available in the SEISAN system (Havskov, 1997). Coda Q is calculated for a series of events and stations at given frequencies. The average Q values are calculated and a Q vs f curve is fitted to the calculated values. An example of the output of the program is shown in Figure 2.

Primarily all data groups and combinations were analysed using window lengths of 10, 15 and 20 sec. (Table 1 and Figure 3). The spreading parameter was selected to be 1, which assumes that the coda waves are body waves. The start of the coda window was initially selected at twice S-wave travel time from the origin, because the general form of the coda is established often after 2 times the S travel time from the origin and always after 3 times the S travel time from the origin (Rautian and Khalturin, 1978). The signal to noise ratio is calculated from the ratio between the rms amplitude at the end of the coda signal and the noise before the P phase. In this case a window of 3 sec. was used and values with signal to noise ratios less than 5 were rejected. For each trace, a value of Q was calculated using equation (3) and results with correlation coefficients of less than 0.5 were not used. A(f, t) was obtained by bandpass-filtering the coda window trace data using a 6 pole Butterworth filter centered at frequency, f, about one octave wide, and calculating rms values using a sliding window of length $5/f$ sec. The center frequencies and bandwidths were selected to 1, 2, 4, 8, and 16 Hz and 0.5, 1, 2, 4 and 8 respectively.

The lapse time is measured from the origin time to the start of the coda window. It is generally observed (Kvamme, 1985; Lee et al., 1986; Gusev, 1995) that increasing lapse time and window length will increase Q. The lapse time is related to the region of sampling, since for any given lapse time t, the scatterers responsible for the generation of coda waves are located within an ellipsoid whose surface projection is defined by $x^2/(vt/2)^2 + y^2/((vt/2)^2 - R^2/4) = 1$ (Pulli, 1984) where for a surface source, R is the source-receiver distance, v is the velocity, t is the lapse time, and x and y are the surface coordinates. Thus increasing lapse time, larger areas as well as larger depths are sampled. When using $2t_s$ as lapse time, there is no control over lapse time used (average is calculated) and it might therefore be difficult to compare results from two different areas. Therefore the data sets were also processed with constant lapse time. This means that all events fulfilling the criteria $t \geq 2t_s$ and t= specified lapse time will be used. This obviously will reduce the amount of data.

INITIAL RESULTS

Table 1 and Figure 3 show the first results with standard parameters. As expected, Q increases with frequency and with window length.
The difference in Q values for the different window lengths seem to be consistent with the COM data set giving higher Q values and CIG the lowest. This is particularly evident at higher frequencies. The 20 sec. window has the fewest data points. In most cases, it seems that CEL gives the highest Q value.

With respect to window lengths, the smallest standard deviations are obtained at 1 and 2 Hz for the 15 sec. window while the 10 sec. window give lowest standard deviations at 4, 8 and 16 Hz. This is despite the fact that the 10 sec. window has more data for all frequencies. It is therefore considered that the most suitable window length to use is 15 seconds, partly also because many other studies use 15 sec windows. A 15 sec window is also a compromise between amount of data and quality.

The difference in Q could indicate regional difference in Q, however, as seen in Table 1 and Figure 3, there seem to be some correlation between Q and average lapse time between the data sets. As it will be shown later, the coda Q results are little dependent on lapse time so the significant Q variation as a function of window length must therefore partially be an artifact of the processing. For that reason, it is also important to use the same window length throughout the study.

The next test was therefore to investigate lapse time dependence. For this test, the whole data set and data set 1 (CIG) were used. Figure 4 and Table 2 show the results. As it can be seen, there is only a small variation of Q with increasing lapse time. At 4 Hz, Q increase slightly, at 2 Hz, Q is constant while at 1 Hz, there is a slight decrease. From the table it is seen that the most reliable results are found at 2 Hz since that is the frequency where most data is available. The decrease in Q at 1 Hz might be an artifact of little data and unstable signal. However the small increase in Q at higher frequencies seem real. From global studies (Gusev, 1995) it has been observed that Q at 1.5 Hz increases from about 30 to 120 when using lapse times 10 and 40 respectively. In our study Q at 2 Hz remains constant at about 100 and at 4 Hz, the increase is from 130 to 160 from lapse time 10 to 40 sec. respectively. Thus Q as function of lapse time in El Salvador does not seem to fit global observations. It can be concluded, that at 2 Hz, lapse time has no influence on coda Q while at higher frequencies, there might be an influence, although small. This might indicate little Q dependence with depth.

When calculating the regional Q in El Salvador it thus seems the more important is to have enough data to make a stable average while it is less important to use a fixed lapse time. The regional Q using the 15 window will be considered as the regional reference.

In order to eliminate lapse time effects and make a regional comparison as well as checking the effect of depth, the calculations were redone with a lapse time of 8 sec. (Table 3 and Figure 5). A 10 sec. window had to be used in order to get enough data. The depth effect can now be studied by comparing area 1 to area 4 and 3 to 5. As it can be seen, there is almost no difference, supporting the hypothesis that there is little Q variation with depth.

In terms of regional variation, only area for geothermal field seem to have a Q significantly different from the other areas.

DISCUSSION

The average Q obtained for El Salvador volcanic zone is

$$\mathbf{Q = 52 \pm 5}\ f^{\ \mathbf{0.78 \pm 0.08}}$$

The values were obtained using 484 records of the whole data base. The window length and start time were fixed to 15 sec. and $2t_s$ respectively, because they gave the best results.

Martinez (1994), carried out a study of coda Q for EL Salvador, using regional earthquakes from the subduction zone and found the relation $\mathbf{Q = 52 \pm 1}\ f^{\ \mathbf{1.02 \pm 0.02}}$ for window length and start time 15 sec. and $2t_s$. respectively and using 217 traces. In a regional study for Central America, Ligorría (1995) reported $\mathbf{Q = 68 \pm 7.5}\ f^{\ \mathbf{0.93 \pm 0.09}}$ for a window length 20 sec and time start $2t_s$, the average lapse time was 63.3±22.6 (Ligorria, personal communication). The Q_0 value compares well with the results from this study but not the α value which will be due to differences in lapse time. We can conclude that coda Q in El Salvador obtained in this study is not radically different from values obtained earlier for the region.

In general, lapse time is a very sensitive variable in determining coda Q since it is generally accepted that coda Q increases with depth, at around 2 Hz. In this study, no lapse variation was found at 2 Hz and only a small increase with lapse time at higher frequencies. This can be interpreted as coda Q has little depth dependence. This observation was independently verified by comparing coda Q using very shallow earthquake and deeper crustal earthquakes in the same region. It thus seems that coda Q under the central part of El Salvador is nearly depth independent in contrast to what has been observed generally around the world. Since the area under study is directly under the volcanic chain one might conclude that the volcanism affects the coda Q at the crust.

The local coda Q variation seems very small, even under such a complex area as the volcanic chain. The largest difference is observed between areas Ilopango lake and the Berlin geothermal field, where it seems that the geothermal field has the highest Q, at least at higher frequencies. This might be explained by the exploration activity since similar high Q observation have been reported. For example Majer and McEvilly (1979) found higher Q value for stations in the production zone at the Geysers geothermal field with respect to stations outside it. In our study, it cannot be concluded that the geothermal field affects the scattering since there are no observations from before the geothermal production started.

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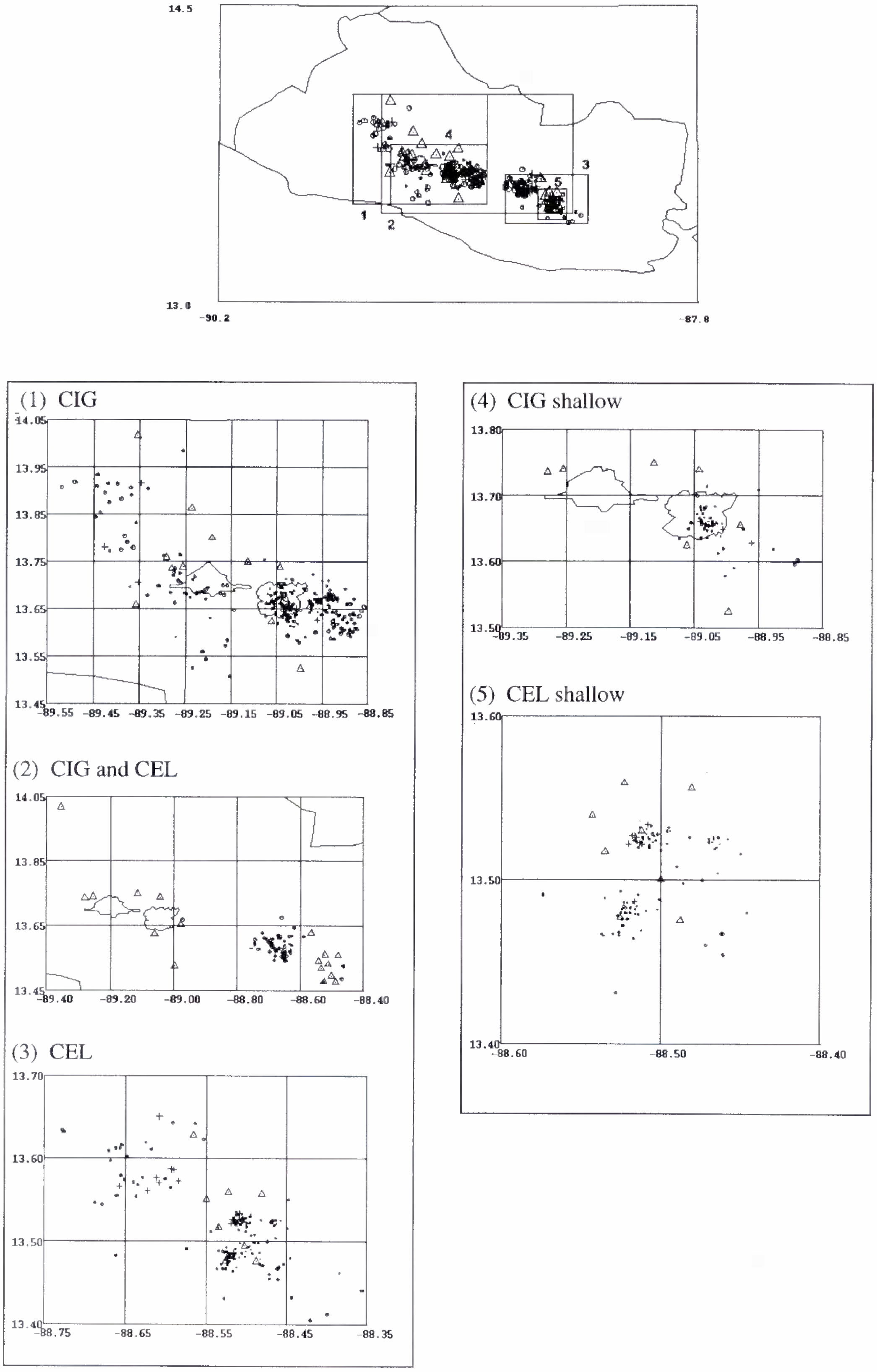

Figure 1. The areas used.
Each area shows the event-station combination. Circles and crosses are event epicenters. crosses indicate no magnitude is calculated while the circles have a size proportionally with the magnitude and triangles are seismic stations. CEL network is located between longitude 88.57° W and 88.47° W, the another stations are from CIG network.

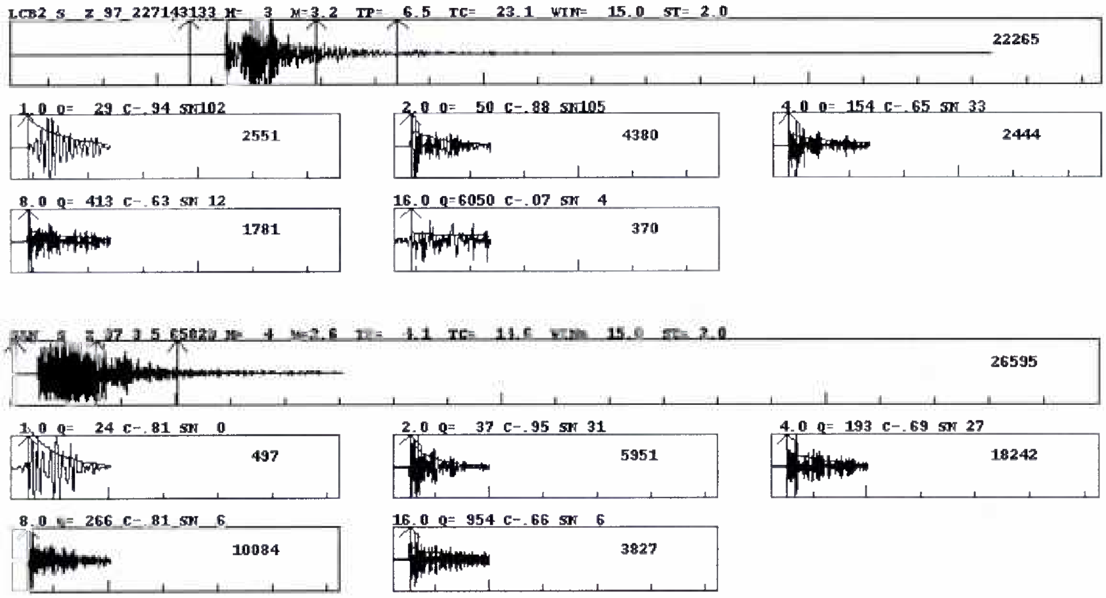

Figure 2. Example of a fit of the envelope for two stations.
LCB2 is from CIG network, SAN is from CEL network. The small plots show the analysis for different central frequencies. The abbreviations are: H: focal depth, M: magnitude, TP: P travel time, TC: start time of coda window relative to origin time, WIN: coda window length, ST: start time of coda window measured in S-wave travel time, Q: estimate of Q value, C: correlation coefficient, S/N: signal-to-noise ratio.

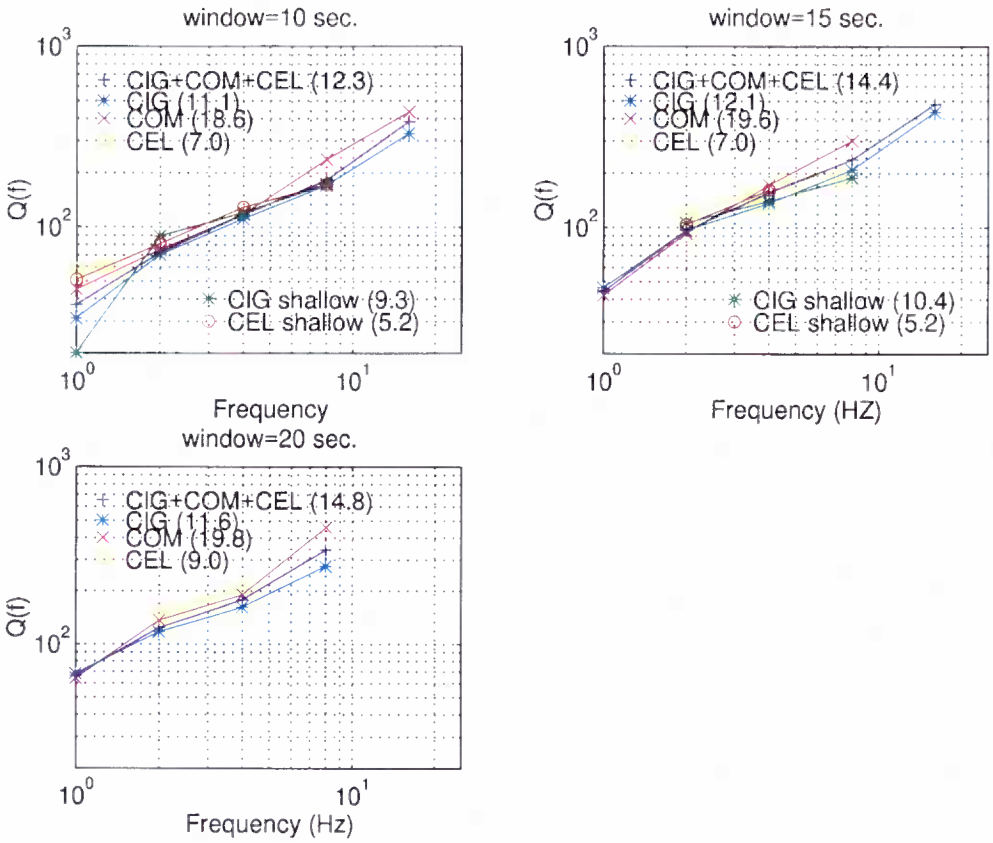

Figure 3. Q as a function of frequency.
Using a start time of 2 times the S-travel time for the different areas (Figure 1). The numbers in bracket are the average lapse times. Window is the coda window length.

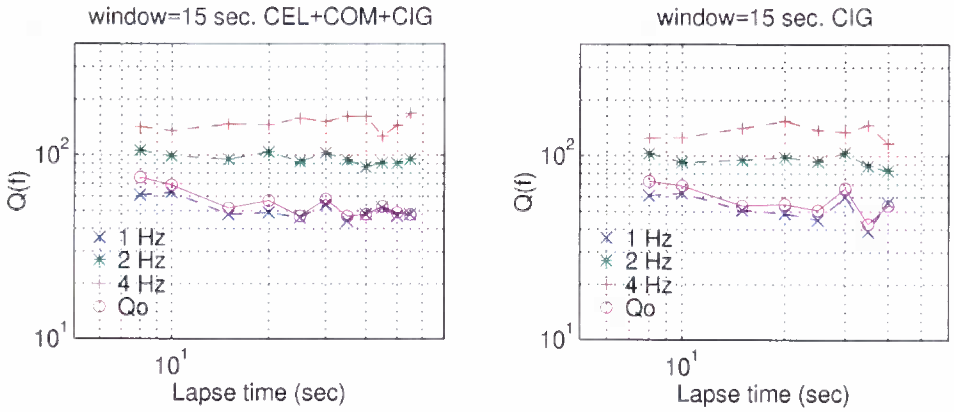

Figure 4 . Q as a function of lapse time.

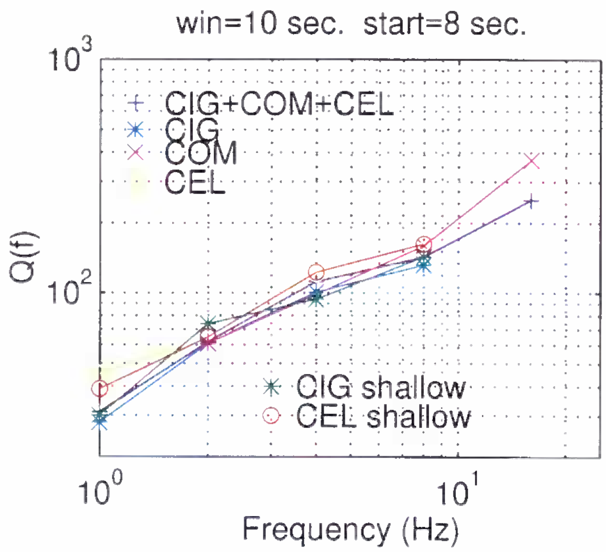

Figure 5. Q as a function of frequency for a fixed lapse time of 8 sec.

Table 1: Different coda Q value for the groups of data.
The lapse time was set to 2 times the S-travel time. The areas are described in the text. The number in brackets for each area, is number of events available. Lapse time is average lapse time, f is Frequency, σ is standard deviation, N is number of useful records, *** are no values, Q_0 and α are the best fit parameter to the equation $Q = Q_0 f^{\alpha}$.

	coda Q for window length =20 sec.																	
data	CIG [325]			COM [62]			CEL [166]			CIG+COM+CEL			GIG [57] (Ilopango lake)			CEL [109] (geothermal field)		
f	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N
1.0	68	33	21	64	30	21	***	***	***	66	32	42	61	31	4	***	***	***
2.0	117	41	90	137	52	49	146	40	5	124	45	144	151	61	19	126	25	3
4.0	162	58	54	190	61	55	206	87	15	178	64	124	145	38	8	228	129	8
8.0	274	102	15	457	148	14	***	***	***	340	152	29	239	89	2	325	***	1
16.0	***	***	***	1119	158	3	***	***	***	1119	158	3	***	***	***	***	***	***
total			180			142			20			342			33			12
$Q_0 f^{\alpha}$	$74 \pm 6f^{0.61 \pm 0.07}$			$67 \pm 11f^{0.86 \pm 0.13}$			$104 \pm {**}f^{0.50 \pm **}$			$70 \pm 8f^{0.74 \pm 0.10}$			$92 \pm 32f^{0.47 \pm 0.29}$			$79 \pm 15f^{0.74 \pm 0.13}$		
lapse time	11.60±6.84			19.81± 6.69			8.97± 3.00			14.85 ± 7.84			10.13±6.01			6.23±1.80		

(A)

	coda Q for window length =15 sec.																	
data	CIG [325]			COM [62]			CEL [166]			CIG+COM+CEL			GIG [57] (Ilopango lake)			CEL [109] (geothermal field)		
f	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N
1.0	46	22	24	42	22	28	88	**	1	44	23	53	34	25	2	***	***	***
2.0	96	36	102	93	38	55	113	38	9	96	37	166	106	28	14	104	36	6
4.0	136	47	79	172	54	79	170	59	46	156	55	204	140	30	11	161	55	31
8.0	208	83	32	302	107	22	206	16	3	237	99	57	188	48	6	213	***	1
16.0	434	174	3	714	***	1	***	***	***	481	203	4	***	***	***	***	***	***
total			240			185			59			484			33			38
$Q_0 f^{\alpha}$	$56 \pm 6f^{0.67 \pm 0.09}$			$46 \pm 3f^{0.95 \pm 0.05}$			$84 \pm 9f^{0.49 \pm 0.08}$			$52 \pm 5f^{0.78 \pm 0.08}$			$62 \pm 20f^{0.58 \pm 0.22}$			$70 \pm 8f^{059 \pm 0.08}$		
lapse time	12.11 ± 6.89			19.62 ± 7.63			7.05 ± 3.37			14.36 ± 8.17			10.37 ± 5.87			5.17 ± 1.53		

(B)

	coda Q for window length =10 sec.																	
Data	CIG [325]			COM [62]			CEL [166]			CIG+COM+CEL			GIG [57] (Ilopango lake)			CEL [109] (geothermal field)		
f	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N
1.0	31	26	42	45	26	35	58	27	7	37	30	84	20	15	4	51	22	5
2.0	70	35	113	75	47	65	72	40	27	72	39	205	89	39	21	81	23	10
4.0	111	36	157	118	44	80	127	53	86	117	42	323	120	46	23	129	55	58
8.0	170	67	87	237	72	36	173	66	48	182	73	171	173	51	10	172	61	38
16.0	329	137	7	435	110	7	560	***	1	383	143	15	243	114	2	560	***	1
total			406			223			169			798			60			112
$Q_0 f^{\alpha}$	$38 \pm 4f^{0.76 \pm 0.08}$			$42 \pm 3f^{0.79 \pm 0.05}$			$53 \pm 8f^{0.60 \pm 0.09}$			$41 \pm 3f^{0.75 \pm 0.05}$			$44 \pm 16f^{0.71 \pm 0.23}$			$56 \pm 9f^{0.57 \pm 0.09}$		
lapse time	11.12 ± 6.09			18.62 ± 7.50			7.00 ± 3.62			12.34 ± 7.43			9.35 ± 6.52			5.20± 1.69		

(C)

Table 2: Coda Q value for different frequencies and lapse times for events from CIG+COM+CEL and CIG data base.
f is frequency, σ is standard deviation, N is number of useful records, *** are no values, Q_0 and α are the best fit parameters to the equation $Q = Q_0 f^{\alpha}$.

LAPSE	FREQUENCY (HZ)															CIG+COM+ CEL
TIME	1			2			4			8			16			
(SEC.)	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Qof^{α}
8	61	13	7	106	35	53	143	55	59	158	43	19	515	***	1	$76 \pm 11f^{0.43\pm0.11}$
10	63	23	8	99	32	66	136	51	63	165	56	12	740	***	1	$69 \pm 9f^{0.49\pm0.11}$
15	48	38	27	95	34	117	148	50	119	282	96	26	776	***	1	$52 \pm 4f^{0.79\pm0.07}$
20	49	20	44	104	38	127	147	52	105	252	124	16	628	***	1	$57 \pm 6f^{0.73\pm0.10}$
25	46	22	42	92	33	123	159	60	70	298	164	16	918	198	3	$47 \pm 3f^{0.91\pm0.06}$
30	54	29	47	103	36	89	153	59	58	228	130	16	708	289	3	$58 \pm 5f^{0.73\pm0.08}$
35	44	25	34	94	35	65	163	68	31	246	92	4	568	***	1	$47 \pm 3f^{0.90\pm0.07}$
40	48	32	37	86	31	45	163	73	28	219	180	2	632	***	1	$48 \pm 2f^{0.86\pm0.04}$
45	52	25	23	91	26	45	127	61	16	240	140	7	743	***	1	$53 \pm 5f^{0.73\pm0.08}$
50	47	27	31	90	27	37	146	54	14	202	96	3	521	***	1	$49 \pm 3f^{0.80\pm0.06}$
55	48	27	21	90	31	23	169	83	14	294	102	2	***	***	***	$48 \pm 1f^{0.90\pm0.03}$
60	35	18	22	92	31	17	138	93	6	272	148	2	***	***	***	$38 \pm 5f^{1.031\pm0.14}$

(A)

LAPSE	FREQUENCY (HZ)															CIG
TIME	1			2			4			8			16			
(SEC.)	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Qof^{α}
8	61	13	7	103	37	38	125	44	31	152	42	15	515	***	1	$73 \pm 11f^{0.41\pm0.11}$
10	63	23	8	92	27	50	126	38	42	139	35	7	***	***	***	$69 \pm 6f^{0.41\pm0.07}$
15	51	45	23	95	35	89	142	48	55	267	93	17	***	***	***	$54 \pm 4f^{0.74\pm0.07}$
20	49	21	28	98	35	72	155	61	36	197	92	8	***	***	***	$55 \pm 6f^{0.73\pm0.11}$
25	45	20	28	93	31	70	138	61	26	199	91	6	***	***	***	$51 \pm 6f^{0.75\pm0.13}$
30	60	31	28	104	39	49	135	54	28	153	80	5	***	***	***	$67 \pm 8f^{0.52\pm0.12}$
35	39	19	19	88	29	38	147	61	19	219	65	3	568	***	1	$43 \pm 4f^{0.91\pm0.09}$
40	56	30	22	83	29	26	117	37	11	219	180	2	632	***	1	$54 \pm 5f^{0.65\pm0.10}$
45	50	22	17	94	26	22	95	25	9	197	89	5	743	***	1	$53 \pm 9f^{0.65\pm0.16}$

(B)

Table 3: Coda Q value for different frequencies and lapse time fixed to 8 sec.
Events are selected from CIG (Ilopango lake) and CEL (geothermal field) have focal depth between 0 and 5 km. The number in brackets for each area, is number of events available, f is Frequency, σ is standard deviation, N is number of useful records, *** are no values, Q_0 and α are the best fit parameter to the equation $Q = Q_0 f^{\alpha}$.

	coda Q for window length =15 sec. and start time = 8.0 sec.																	
data	CIG [325]			COM [62]			CEL [166]			CIG+COM+CEL			GIG [57] (Ilopango lake)			CEL [109] (geothermal field)		
f	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N
1.0	61	13	7	***	***	***	***	***	***	61	13	7	65	3	2	***	***	***
2.0	103	37	38	116	21	3	113	28	12	106	35	53	115	46	10	108	30	9
4.0	125	44	31	226	52	4	162	57	24	143	55	59	114	26	5	158	57	20
8.0	152	42	15	204	72	2	167	11	2	158	43	19	148	17	3	159	***	1
16.0	515	***	1	***	***	***	***	***	***	515	***	1	***	***	***	***	***	***
total	92			9			38			139			20			30		
$Q_0 f^{\alpha}$	$73 \pm 11 f^{0.41 \pm 0.11}$			$97 \pm 66 f^{0.46 \pm 0.37}$			$88 \pm 20 f^{0.41 \pm 0.16}$			$76 \pm 11 f^{0.43 \pm 0.11}$			$86 \pm 16 f^{0.27 \pm 0.15}$			$81 \pm 19 f^{0.46 \pm 0.17}$		
lapse time	8.0			8.0			8.0			8.0			8.0			8.0		

(A)

	coda Q for window length =10 sec. and start time = 8.0 sec.																	
data	CIG [325]			COM [62]			CEL [166]			CIG+COM+CEL			GIG [57] (Ilopango lake)			CEL [109] (geothermal field)		
f	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N	Q	σ	N
1.0	28	15	15	***	***	***	45	25	4	31	17	19	30	14	3	39	19	3
2.0	61	34	39	61	13	2	65	23	20	62	31	61	74	35	19	65	24	17
4.0	101	35	49	145	***	1	121	43	65	112	41	115	94	30	8	123	42	52
8.0	132	32	33	160	70	3	165	35	18	143	38	54	143	16	4	163	37	13
16.0	189	115	2	371	121	2	***	***	***	251	153	4	***	***	**	***	***	***
total	138			8			107			253			34			85		
$Q_0 f^{\alpha}$	$36 \pm 5 f^{0.68 \pm 0.10}$			$35 \pm 12 f^{0.81 \pm 0.14}$			$45 \pm 8 f^{0.68 \pm 0.11}$			$38 \pm 6 f^{0.70 \pm 0.10}$			$44 \pm 10 f^{0.60 \pm 0.18}$			$43 \pm 8 f^{0.71 \pm 0.13}$		
lapse time	8.0			8.0			8.0			8.0			8.0			8.0		

(B)