Quality factor of seismic coda waves from earthquakes in northern Morocco

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Abstract. The main objective of this work is to analyze seismic attenuation ($1/Q_c$) using a single backscattering model hypothesis of Aki and Chouet (1975). For this purpose, the recordings of 66 local earthquakes (epicentre distance < 100 km) during 2008 in Northern Morocco have been used with a magnitude (Ml) less than 4. The Q_c quality factor values have been computed at four central frequencies 0.75, 1.5, 3, 6 and 12 Hz and analyzed for two horizontal and vertical components for performing the average values. Four lapse time windows seconds from 30 to 60 duration with a difference of 10 seconds have been analyzed to study the lapse time dependence of Qc. We obtained a strong average frequency dependence follow a power law $Q_n=Q_0f^n$ where Q_0 is Q_c at 1Hz and n is the power of frequency dependent .The frequency dependent relationships obtained are $Q_c=(143.75\pm1.09)f^{(0.864\pm0.006)}$ for the vertical component , $Q_c=(149.12\pm1.08)f^{(0.85\pm0.05)}$ and for the N component , and $Q_c=(140.42\pm1.81)f^{(0.902\pm0.04)}$ for the E component. The values estimated of coda Q shows independent on the component of wave motion consistent with (Jen-Kuang Chung 2009 and Priyamvada Singh 2012), thus only one component sufficient to treat the attenuation in this region. The mean values of the estimated Q_c of the vertical component vary from 76 (at 0.75) to 1147.6 (at 12 Hz) for 30 seconds coda window length, for 40 seconds coda window length Qc vary from 122.48 (at 0.75) to 1255 (at 12 Hz) while for 50 seconds coda window length Q_c vary from 141.4 (0.75) to 1420.8 (at 12 Hz) . Similarly for 60 seconds coda window length Q_c vary from 173.89 to 1495. The increase in Q_c values with lapse time shows the depth dependence which agree with many studies. The results obtained with this model are presented and then compared to results from the literature.

1. Introduction

Morocco is a transition zone between the African and European plates [5]. The seismic history mentions several catastrophic earthquakes in this region [4,5,12]. In particular, Northern Morocco has been most affected by earthquakes in the past .The last relevant one is 24th February 2004 earthquake (Mw = 6.1) which caused great damage in Al Hoceima city and the surrounding area [4,5]. One of the important factors in the assessment of the earthquakes in a region is to know the attenuation characteristics [1,2,10,7,15,16,23]. The attenuation propriety is described by the quality factor Q [1,2].Numerous studies have been done worldwide to understand the attenuation during its propagation in the earth [1,2,3,6,7,9,10,13,15,17,20,21].

Single Backscattering model of Aki and Chouet [1] has been chosen to be used in the present study because it facilitates the comparison with other regions of the world. The results will be compared with other Q measurements in other region in the world[15]. To the best of your knowledge, this is the first study of seismic wave attenuation in the region.

2. Data

The seismograms used for this research where recorded by 26 seismological stations during 2008. All of the stations are 3-component broadband sensors (Trillium 40 broadband from Nanometrics) where used for the network. For the analysis we used only 66 local earthquake recorded by a station network operating in the area . The magnitudes of the analyzed events range from 0.7 to 3.4. Data were recorded digitally at 100 samples/s. Only good quality seismograms were processed, with signal to noise (S/N) greater than 3 for a given data set. We took only Q_c estimates greater than 0.5 as correlation coefficients of the linear regression. The detailed information regarding these events is provided in Figure 1. The Q_c value are calculated through using CODAQ subroutine of seisan 8.0 [11] .The origin time, epicenter locations and magnitudes of the earthquakes used were determined by SEISAN Software [11].

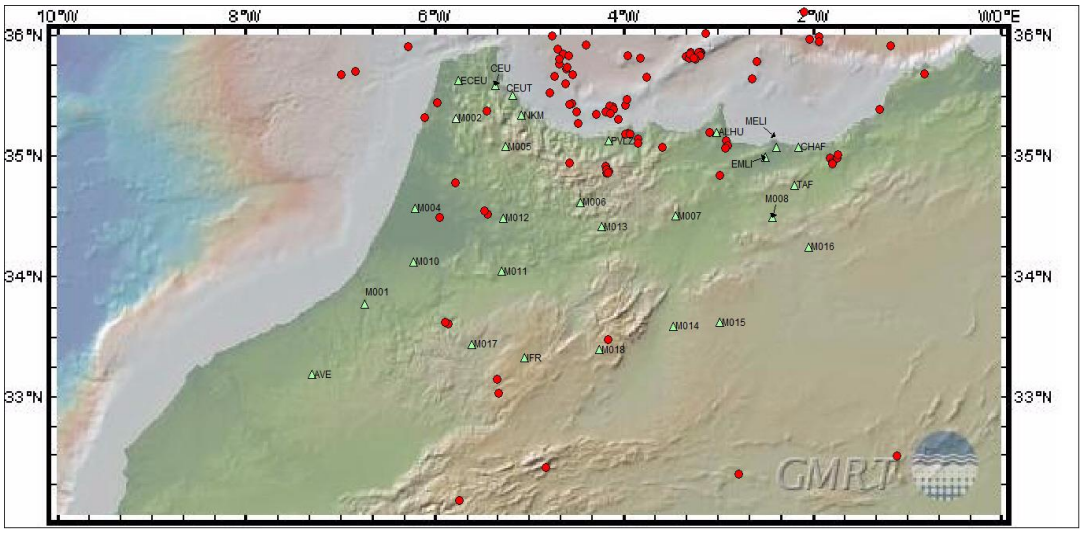

Fig.1. Locations of the events used in this study .Circles are the events and triangles are the stations selected for coda Q_c [25].

3. Methods of Analysis

In the single backscattering method according to Aki and Chouet [1], the displacement of coda waves is described as:

$$A(f,t) = S(f)t^{-1}\exp(\frac{\pi f.t}{Q_c}) \quad (1)$$

where Q_c is the quality factor ,t^{-1} is the lapse time and S(f) is the coda source factor at radial frequency .By taking the natural logarithms of equation (1) , the equation can be written as:

$$\ln[A(f,t).t] = C - b.t \quad (2)$$

where b and C equal to $-\pi f/Q_c$ and ln[S(f)] respectively. Q_c can be obtained at different frequency f from the slope (=b) and include the country.

4. Results

Using the data sets of local earthquakes and adopting the single backscattering model, the coda wave is analyzed on the three components, for performing the average values of this parameter. The figures below shows the results .

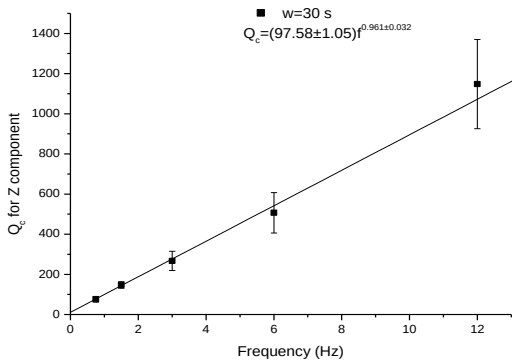

Fig.2. Plot of mean value of Q_c for w=30s for Z component.

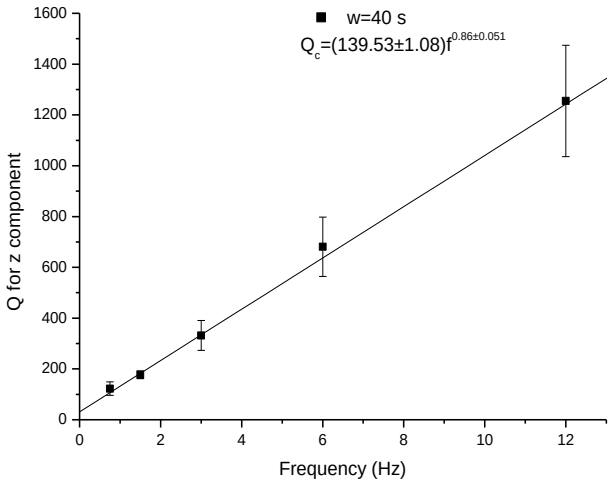

Fig.3. Plot of mean value of Q_c for w=40s for Z component.

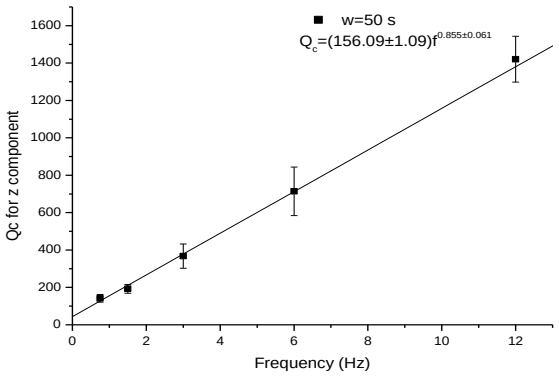

Fig.4. Plot of mean value of Q_c for w=50s for Z Component.

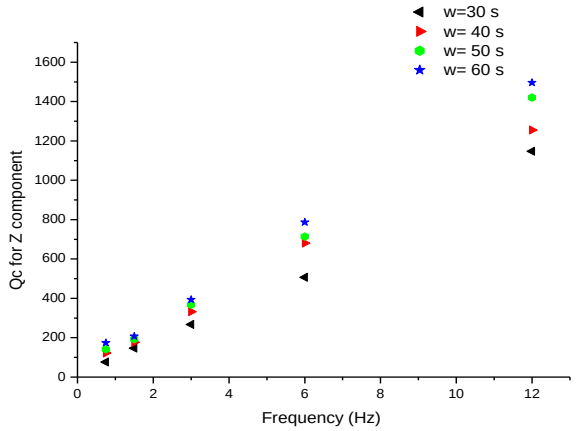

Fig.5. A comparison of the mean values of Q_c as a function of frequency obtained at four lapse time windows (Z component)

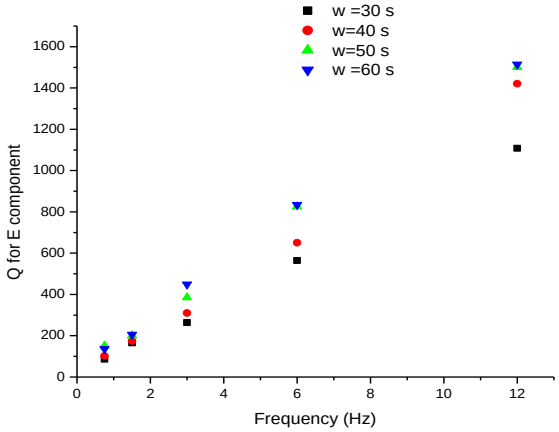

Fig.8. A comparison of the mean values of Q_c as a function of frequency obtained at four lapse time windows (E component).

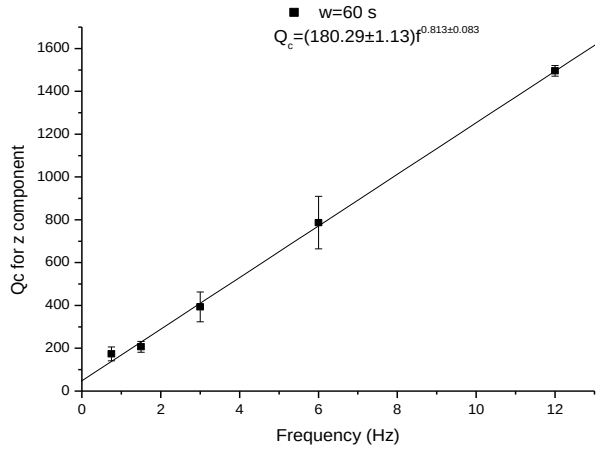

Fig.6. Plot of mean value of Q_c for w=60s for Z component.

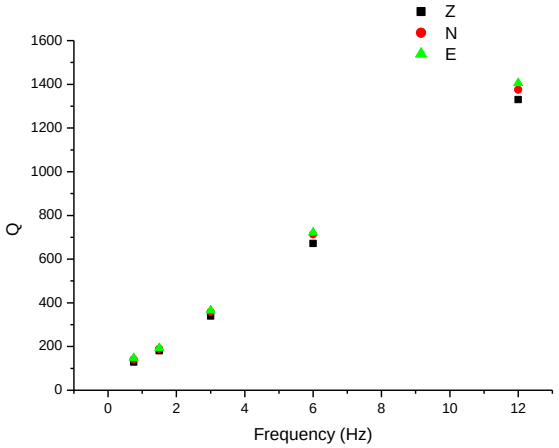

Fig.9. Comparison between the coda wave on the three component.

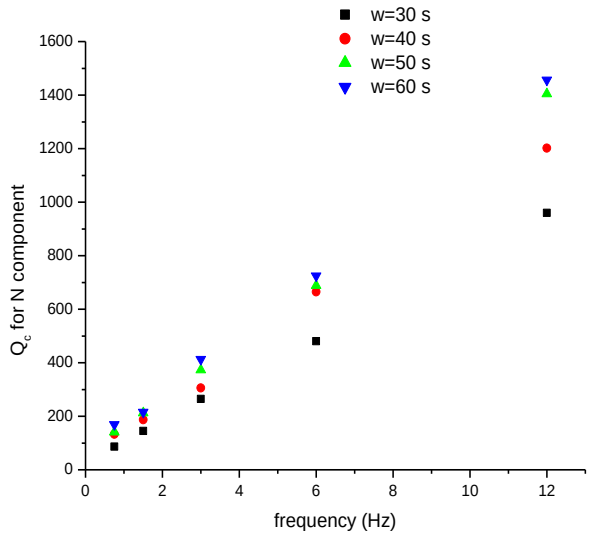

Fig.7. A comparison of the mean values of Q_c as a function of frequency obtained at four lapse time windows (N component).

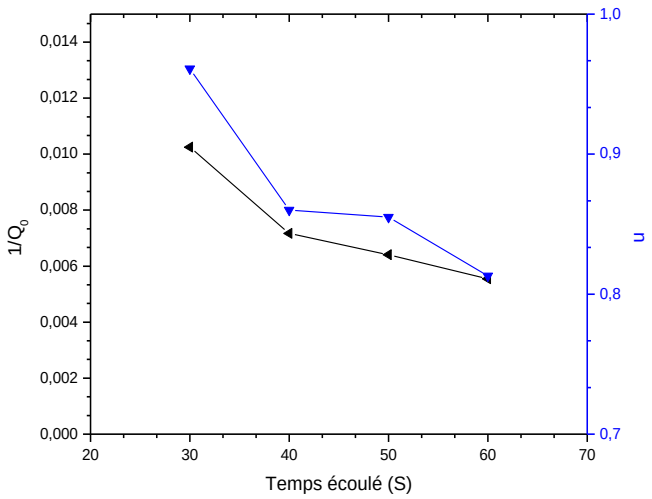

Fig.10. Comparison of average $1/Q_0$ and *n* with lapse time for vertical component

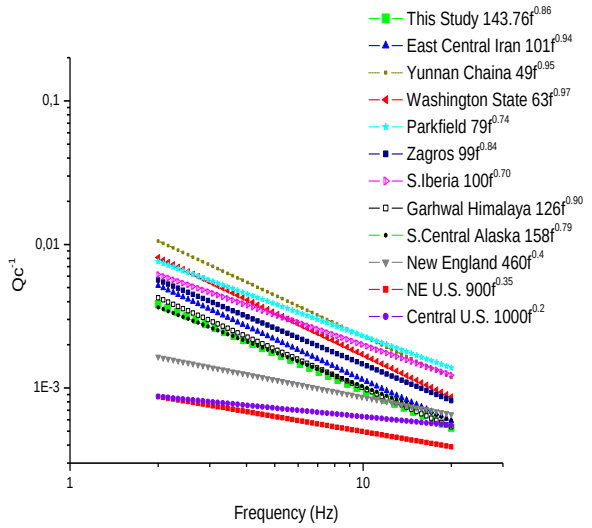

Fig.11. Comparison of coda-Q_c of North of Morocco region with reported coda-Q_c of other regions of the world.

5. Discussion and conclusions

In the present study, the seismic attenuation characteristics have been estimated for Northern Morocco region. The coda wave of 66 earthquakes recorded in this region during 2008 , have been analyzed for four windows lengths (30 s ,40 s ,50 s,60 s) at five frequency bands with central frequency in the range of 0.75 Hz to 12 Hz .Two horizontal and the vertical components were analyzed for performing the average values. Our estimation shows that the quality factor of coda wave is independent on the component of wave motion , these results are very good agreement with several previous [6,23]. The estimated coda values on the vertical component, for the lapse time window of 30 sec, vary from 37 to 171 at 0.75 Hz and from 1643 to 562 at 12.0 Hz, while the average value of coda value along with the standard error is $Q= (97.58 \pm 1.05)f^{(0.961 \pm 0.032)}$ .The observed Q_c values increase with increasing lapse time at all frequency bands. A frequency dependent relationship, $Q= 143.7f^{0.86}$, also has been obtained for the region of Northern Morocco. The analysis of coda waves at four lapse time windows shows that the coda values increase with increasing lapse time at all frequency bands.

The frequency dependent average of coda value on vertical component are as:

$Q_c=(97.58 \pm 1.05)f^{(0.961 \pm 0.032)}$ for w=30 s
$Q_c=(139.53 \pm 1.08)f^{(0.86 \pm 0.051)}$ for w=40 s
$Q_c=(156.09 \pm 1.09)f^{(0.855 \pm 0.061)}$ for w=50 s
$Q_c=(180.29 \pm 1.13)f^{(0.813 \pm 0.083)}$ for w=60 s

The attenuation parameters ,Q_0 (Q_c at 1Hz) , were estimated in 97-180 range .These values appear higher than those obtained by others authors for tectonically and seismically active region such as Yunnan ,China and Washington State , and lower to those observed for inactive or stable region such as New England , South India , NE USA [15].

and North Iberia. The frequency dependence coefficients [2] vary between 0.8 and 0.9, which indicates moderately high seismic hazard [22].

References

1. Aki K J Geophys Res **74**:615–631 (1969)
2. Aki K J Geophys Res **85**:6496–6504(1980)
3. Aki K J. Geophys. Res. **80**, 3322–3342 (1975)
4. S. Benchekroun, A. Iben brahim (April 2013), International Journal of Engineering Inventions , **2**, Issue 6 ,PP: 01-08
5. Cherkaoui T-E, (1990), Bulletin de l'Institut Scientifique, Rabat, **14**, pp : 25-34
6. Jen-Kuang Chung, (2009) , Earth Planets Space, **61** 1077–1088
7. A.A. Dobrynina et al. (2011) Russian Geology and Geophysics **52** 555–564,
8. A.A. Dobrynina (2011) Physics of the Earth and Planetary Interiors **188** 121–126
9. Gupta, S.C., Teotia, S.S., Gautam, N.,(1998) Pure Appl. Geophys. **153**, 713–731.
10. Havskov J Bull Seismol Soc Am 79:1024–1038 (1989)
11. Havskov,J and Ottemoller, L , Seismological Research Letters **70**, Number5 September/October (1999)
12. D. Khattach et al. (2013) Journal of Geodynamics **68** 37– 48
13. Naresh Kumar ,(2005), Physics of the Earth and Planetary Interiors **151** 243–258
14. Lucas Vieira Barros , (2011) ,J Seismol, **15**:391–409
15. Ma'hood,M , J Seismol , 13:125–139 ,(2009)
16. Mak, S., Chan, L.S., Chandler, A.M., Koo, R., (2004), J. Asian Earth Sci. **24**, 127–136.
17. Mitchell, B.,(1981). Bull. Seismol. Soc. Am. **71**, 1531–1538
18. Morozov, I.B,(2008), J. Int. **175**, 239–252
19. S. Mukhopadhyay , (2008), Geophys. J. Int. **172**, 1055–1065
20. Pulli, J.J., (1984). Bull.Seismol. Soc. Am. **74**, 1149–1166.
21. Rautian, T.G., Khalturin, V.I., (1978), Bull. Seismol. Soc. Am.**68**, 923–948
22. Singh,C, , (2012), Geologica Acta , **10** , N 3 , September, 309 – 318
23. Priyamvada Singh, (2012) , International Journal of Civil Engineering & Technology (IJCIET), **3**(2) 279 – 291
24. L. Telesca, (2009),Nat. Hazards Earth Syst. Sci **9**, 2063–2066
25. William B. F. Ryan and Suzanne M. Carbotte,(2009) Geochem. Geophys. Geosyst., **10**, Q03014