Q_P, Q_S AND Q_C ATTENUATION PARAMETERS IN THE CRUST OF ALBORZ REGION, IRAN

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The attenuation of P, S and coda waves has been inferred for the Alborz region (Iran) using seismic waveforms of local earthquakes occurred within the studied area for the period from October 20th, 2009 to December 22nd, 2010. The data was provided by using three seismic networks, two of which were permanent networks (IIEES and IRSC seismic network) and one temporary network. The format of all waveforms has been changed to the SEISAN waveform format. The dataset used in this study was consist of 380 well-located local earthquakes ($2 < M_L < 5.7$). The hypocentral distance range used in this study was from 30 to 130 km. More than 20,000 good quality waveforms have been automatically processed for quality factor determination of P, S and coda waves (Q_P, Q_S and Q_C). The single backscattering (SBS) and extended coda normalization method (ECNM) have been used to determine Q_P, Q_S and Q_C value at seven frequency bands (0.375, 0.75, 1.5, 3, 6, 12, 24 Hz). The frequency dependence relation of Q_P, Q_S and Q_C has been determined and reported in Table 1.

The quality factor of coda waves (Q_C) has been determined by analyzing the decay rate of coda envelope with the concept of single backscattering method (Aki and Chouet, 1975; Sato *et al.*, 2012). The amplitude of coda wave's envelope, at each frequency band is calculated by using the following formula:

$$A_c(f,t_c) = \sqrt{x(f,t_c)^2 + H[x(f,t_c)]^2} \quad (1)$$

The amplitude of coda wave's envelope $A_C(f, t_C)$, in central frequency (f) at lapse time (t_c), (measured from the origin time of the seismic event) can be shown:

$$\ln[A_c(f,t_c).t_c] = \ln[I(f)A_0(f)] - \frac{\pi f}{Q_c}t_c \quad (2)$$

Based on single backscattering method (SBS), a seismic code (AUTO-Qcoda) has been developed in order to automatically estimate coda-Q values at different lapse time windows mentioned in Table 1 (Farrokhi *et* al., 2014). The frequency dependence of coda-Q has been determined and reported in Table 1.

According to the extended coda normalization method (Yoshimoto *et al.*, 1993), quality factor of P and S-waves can be determined by using the following formula:

$$\langle ln\left[\frac{A_P(f,r)}{A_C(f,t_c)}G(r)\right]\rangle_{r\pm\Delta r} = -\frac{\pi f}{V_P Q_P(f)}r + const_P(f) \quad (3)$$

$$\langle ln\left[\frac{A_S(f,r)}{A_C(f,t_c)}G(r)\right]\rangle_{r\pm\Delta r} = -\frac{\pi f}{V_S Q_S(f)}r + const_S(f) \quad (4)$$

Where A_p and A_S are the maximum amplitude of direct P and S-waves at hypocentral distance of r, respectively, for a filtered seismogram with central frequency of f. A_C is the average amplitude of coda wave at lapse time t_c and G(r) is the geometrical spreading correction factor that consider to be r^1 for maximum amplitude of body waves at distances lower than 100 km. V_p and V_s are the average velocity of P and S waves which are 6 and 3.5 km/s, respectively. The symbol $_{r\pm\Delta r}$ mean averaging within hypocentral distance of r±Δr. In this study the Δr is considered to be 10 km. A seismic code (AUTO-QP&S) has been developed to automatically estimate the quality factor of P and S-waves (Farrokhi and Hamzehloo, 2014) and results is reported in Table 1.

Table 1. Frequency dependence relation calculated in this study

Quality factor	Qp	Qs	Qc (40 s)	Qc (50 s)	Qc (65 s)	Qc (85 s)
Frequency dependance	$59\pm1f^{1.04\pm0.05}$	$104\pm1f^{0.89\pm0.02}$	$69\pm1f^{0.97\pm0.01}$	$78\pm1f^{0.97\pm0.01}$	$105\pm1f^{0.93\pm0.01}$	$123\pm1f^{0.89\pm0.01}$

The estimated values of quality factor of P, S and coda waves are in the range of those of tectonically active regions of world. Based on the relation between lapse time and mean penetration depth (Pulli, 1984), the increase in the value of Q_C values with lapse time could be related to existence of low dissipating layer at higher depth.

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