Estimation of quality factor Q, using Lg coda for the northern part of Iran (Kopeh Dagh, Alborz, Azarbayejan and Caspian Sea block)

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(Received: 17 Feb 2014, Accepted: 17 Feb 2015)

Summary

In many seismological applications, the Earth is considered as a perfectly elastic, homogeneous, and isotropic body. Although this assumption is approximately valid, it is known that seismic waves pass through the real Earth that is anelastic, inhomogeneous and anisotropic.

We consider four processes that can reduce wave amplitude, i.e.: geometrical spreading,

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scattering, multi-pathing, and anelasticity. The first three are elastic processes, in which the energy in the propagating wave field is conserved. By contrast, anelasticity, sometimes also called intrinsic attenuation, results because the kinetic energy of elastic wave motion is lost to heat by permanent deformation of the medium (Stein and Wysession, 2002). Intrinsic attenuation as one of the factor affecting the attenuation of seismic wave during propagation is discussed in terms of quality factor. Estimation of quality factor is valuable for seismic hazard assessment, ground motion simulation, attenuation relationships, and other seismological studies.

The quality factor is an effective Q, which includes other damping mechanisms. The effective Q is the sum of intrinsic and additional attenuation:

$$\frac{1}{Q_{eff}} = \frac{1}{Q_{int}} + \frac{1}{Q_{add}}$$

Generally, it is impossible to control all effects and the result is an effective Q (Tonn, 1989)

Regional variations in crustal Q are often studied using Lg waves. The most prominent regional phase is the Lg wave that was identified by Press and Ewing (1952). Lg phase is commonly observed in the continental crusts. It is variously described as a superposition of higher mode surface waves or trapped post-critical S waves. Lg phase does not propagate efficiently in the thin oceanic crust. Lg phase has also been observed to have large amplitude in the group velocity windows of 2.8 - 3.5 km/s (Cara et al., 1981).

We applied the stack spectral ratio (SSR) method originally developed by Xie and Nuttli (1988) to obtain Q_0 (Q at 1 Hz) and its frequency dependence (η) of each path integral between different station-event pairs in frequency range of 0.2 - 5.0 Hz for the northern part of Iran (lat. 32 - 40 °N and long. 44 - 62 °E). This part consists of Kopeh Dagh, Alborz-Azarbayejan, Some part of Zagros, some part of Central Iran and the Caspian Sea block. The use of the stacking procedure is a major development in obtaining stable Q (f).

The dataset used in this research consist of the vertical component seismograms from 409 events with magnitude (M_N) greater than 4, occurred during the period of 2006- 2013. According to the results obtained in this study, the maximum Q_0 values are in the range of100 - 500 and maximum frequency dependence values are in the range of 0 - 1. In addition, if it is assumed that $Q = Q_0 f^{\eta}$, the average values of these two parameters are given by $Q = (347 \pm 34)\, f^{(0.7 \pm 0.1)}$ for the entire region. According to the tectonic evidences and seismicity pattern, the study region is tectonically active. Therefore, for active regions, attenuation of seismic waves is increased and the values of Q_0 are reduced because of crust heterogeneity, fractures and energy scattering in fractures.

Table 1 shows Q_0-values obtained for different seismotectonic provinces. Analysis of this table shows that the lowest values of Q_0 characterize the Azarbayejan region and these values are closed to the Alborz region. In addition, Q_0-values of Zagros and Kopeh Dagh regions are similar to each other. Structurally, Kopeh Dagh is similar to Zagros. So, similar values of Q_0 and η are expected for these similar tectonic regions. The low Q_0-values for the Alborz and the Azarbayejan regions compared to the values for Zagros and Kopeh Dagh regions may be due to volcanic mountains in this region. It confirms that for the regions with recent volcanic activities, low Q_0 values are expected. For the central Iran in our study region, the moderate to high Q_0 values are obtained. Because this province is an intraplate environment between Zagros and Kopeh Dagh, thus it can be suggested that for this kind of region, moderate to high Q_0 values are obtained because of the differences in seismicity patterns. The highest Q_0 is for the Caspian Sea that consists of a thin oceanic crust. For this region the number of surface waves modes is reduced and the Lg phase cannot propagate sufficiently long.

Variation of frequency dependence versus quality factor shows different behavior for different seismotectonic provinces. For the Alborz and the Azarbayejan regions, frequency dependence decreases with increasing Q_0 values. For Zagros and Kopeh Dagh, frequency dependence increases with increasing Q_0 values. Overall, we can conclude that similar tectonic regions show similar frequency dependence versus the quality factor.

The quality factor values are plotted versus epicentral distance. It shows a direct relationship between these two parameters and with increasing epicentral distance, the quality factor increases. This trend is not observed in the different seismotectonic provinces. Generally it is expected that with increasing distance from the seismic source, the attenuation of seismic waves is increased. However, several factors such as the regional tectonic conditions, rate of seismicity, sediment thickness and thermal conditions, etc. can affect the value of the quality factor. Since regional tectonic condition has the most important role in determining the quality factor, we cannot solely assess variations of quality factor versus epicentral distance.

Keywords: Quality factor, Lg coda phase, Frequency dependence, Stack spectral ratio method