Variation of the Q-value with the depth in a southeastern part of Korean Peninsula

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1. Introduction

Recently, many works for the seismic wave attenuation have been performed in a southeastern part of Korean Peninsula. The frequency dependent Q-values for S wave studied by several authors show wide variations. It is thought that the discrepancy between them arises from two factors. The one is the treatment of the geometrical spreading coefficient in estimating Q-value. The other is relevant with data sets to be used. Since the estimated Q-values are dependent with the distance, the inverted Q-values from the different composition of data sets become different.

Accordingly the geometrical spreading coefficient was determined directly from the ray approximation method and eliminated from the unknown parameters in this work. Assuming that the Q-value varies with the depth, a three-layer model of a frequency-dependent Q to be uniform in each layer was also inverted from the method of a separation of a source, path, and site effects in terms of the central frequencies in 1.5, 3, 5, 10, 15, and 25 Hz.

2. Method

This study employed the modified method of Petukin and Irikura(2000) for the determination of Q with the depth. We assume that the observed amplitude Fourier spectrum at frequency f at site j from source i is a product of four factors: source, seismic impedance amplification, path attenuation, and site effect plus errors.

$$O_{ij}(f_l) = S_i(f_l)\cdot\left(\frac{\rho_0\upsilon_0}{\rho_i\upsilon_i}\right)^{1/2}\cdot g_{ij}\Pi_k \exp\left(-\pi\frac{r_{ij}^k f_l}{\upsilon_k Q_k(f_l)}\right) \cdot G_j(f_l)\cdot C_{ij}^{\varepsilon}(f_l) \quad \textbf{(1)}$$

Where $O_{ij}(f_l)$ is the observed spectrum at frequency f for the source/site pair ij. $S_i(f_l)$ is the source spectrum, $G_j(f_l)$ is the site effect, $g_{ij} = g_{ij}(\Delta_{ij}, h_i)$ is geometrical spreading factor (Δ is epicentral distance, h is depth), and $Q_k(f_l)$, r_{ij}^k and υ_k are the inelastic attenuation factor, path length, and S-wave velocity inside the k th layer, respectively. The variables ρ_i and υ_i are the density and velocity at the source depth, ρ_0 and υ_0 are the density and velocity at depth of basement under the site. Taking a common logarithm, we can write this in a linear form with observed spectrum, corrected for seismic impedance, on the left-hand side, and source, path, and site effect on the right-hand side.

$$\log O_{ij}(f_l) - \frac{1}{2}\log\frac{\rho_0\upsilon_0}{\rho_i\upsilon_i} = \log S_i(f_l) + \log g_{ij} + \sum_k\left(-\pi\log e\cdot\frac{r_{ij}^k}{\upsilon_k}\cdot\frac{f_l}{Q_k f_l}\right) + \log G_j(f_l) + \log C_{ij}^{\varepsilon}(f_l) \quad (2)$$

$\log S_i$, $\log G_j$ and $f_l / Q_k(f_l)$ are unknown parameters to be determined by linear inversion.

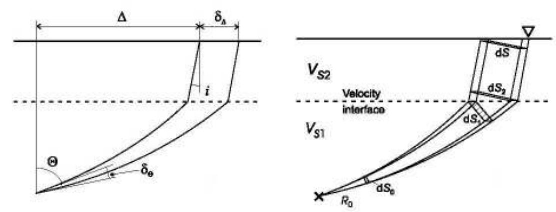

Fig. 1. Scheme of calculation of geometrical spreading. Illustration of definition of the geometrical spreading (left); scheme that explains meaning of variables in equation (5) (right). After Petukhin et al.(2003).

The Q-value was estimated by elimination of geometrical spreading effect using ray approximation. Geometrical spreading assumes that:

$$g(R) = 1/R^n \quad (3)$$

R is a hypocentral distance and n is a geometrical spreading coefficient. We defined the geometrical spreading as broadening of the area of cross section of ray tube emanation from the source, as shown in Fig. 1. Geometrical spreading $g(R)$ expressed to:

$$g = \frac{1}{R_0}\sqrt{\frac{dS_0}{dS}} \quad (4)$$

We can estimate the ratio dS_0 / dS numerically from the spreading of two close rays.

$$g(\Delta) = \sqrt{\frac{\delta_\Theta\cdot\sin\Theta}{\Delta\cdot\delta_\Delta\cdot\cos i}} \quad (5)$$

Here Δ is the epicentral distance and i is the incident angle. It was assumed: parameters δ_Θ, $\cos i$ and

$\sin\Theta$ were estimated numerically from ray tracing (Petukhin et al., 2003).

3. Data and result

Assuming that the Q-value varies with the depth, a three-layer model of a frequency- dependent Q to be uniform in each layer was also inverted from the method of a separation of a source, path, site effects in terms of the central frequencies of 1.5, 3, 5, 10, 15, and 25 Hz.

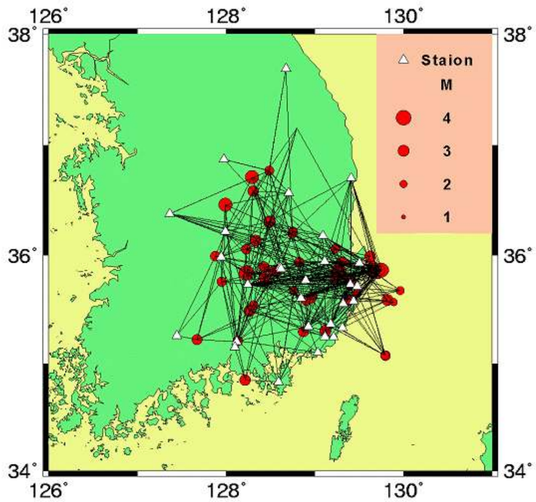

Fig. 2. Distribution of path (line) between earthquakes (circles) and stations (triangles) in a southeastern part of Korean Peninsula used in this study.

The 780 seismograms from 68 earthquakes recorded at 29 seismic stations from 1996 to June 2005 that occurred in the Gyeongsang Basin, southeastern part of Korean Peninsula, were selected for this study(see Fig. 2). This study adopted the Chang and Baag (2006) velocity structure to estimate the Q with depth.

The model for the Q-value corresponding to the seismic wave velocity structure within the crust determined from the least square inversion was presented. Q versus f was calculated:

1st layer: $Q = 12.39 f^{0.8969}$ (6)

2nd layer: $Q = 87.62 f^{0.8373}$ (7)

3rd layer: $Q = 104.40 f^{0.6491}$ (8)

One layer: $Q = 62.55 f^{0.8208}$ (9)

As shown in Fig. 3, the estimated Q-values increased with the increment of the frequency in each layer. The Q-values in the 2nd layer revealed a larger value than those in the 1st layer. However, the values in the 3rd layer showed to decrease rather more than those in the 2nd layer in a high frequency above 5 Hz.

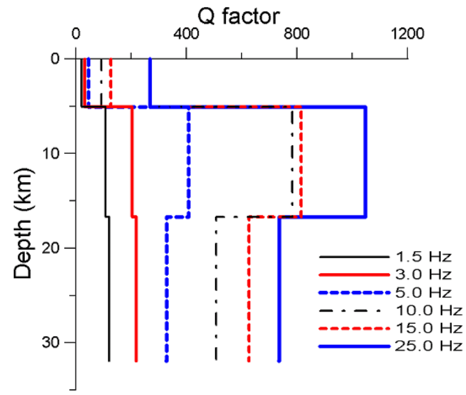

Fig. 3. Quality factor for S-wave with the depth corresponding to the seismic velocity structure proposed by Chang and Baag (2006).

4. Conclusion

The Q-value was estimated by the elimination of the geometrical spreading effect using a ray approximation. The relative amplitude decay with epicentral distance was calculated by using a inverted Q-value. Amplitude decay of the three-layer Q-model was more than the One-layer Q-model. Particularly, if the source is located shallow depth, there is a distinct difference in the amplitude decay with epicentral distance. This result suggests that a attenuation of regional distance should consider a layered Q-model.

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