Scattering and Anelastic Attenuation of Seismic Energy in 
Northern Greece

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Abstract—The relative contribution of scattering ($Q_s^{-1}$) and intrinsic ($Q_i^{-1}$) attenuation to the total S-wave attenuation for the frequencies of 1.5, 3.0, 6.0 and 12.0 Hz has been studied by applying the radiative energy transfer theory. Data of local earthquakes which occurred in northern Greece and were recorded by the permanent telemetered network of the Geophysical Laboratory of the University of Thessaloniki have been used. The results show that in this area the scattering attenuation is dominant over all frequencies while intrinsic attenuation is significantly lower. The estimated $Q_s^{-1}$ and $Q_i^{-1}$ values have frequency dependences of $f^{-0.72}$ and $f^{-0.45}$, respectively. The frequency dependence of $Q_i^{-1}$ is the same as that of the coda $Q_c^{-1}$, obtained by applying the single scattering model, which probably implies that the frequency dependence of the coda wave attenuation is attributed to the frequency dependence of the scattering attenuation. $Q_s^{-1}$ values are very close to scattering attenuation for short lapse times, (10–20 sec), and intermediate between scattering and intrinsic attenuation for the longer lapse times, (50–100 sec). This difference is explained as the result of the depth-dependent attenuation properties and the multiple scattering effects.

Key words: Attenuation, scattering, coda $Q$, northern Greece.

Introduction

Attenuation is one of the basic properties of seismic waves from which the material and physical properties of the earth’s interior can be inferred. The term “attenuation” includes both intrinsic attenuation which is due to the anelastic absorption of wave energy during wave propagation caused by conversion of wave energy into heat, and scattering attenuation due to the heterogeneity of the medium which presents some obstacles to wave propagation. The second mechanism is not associated with real energy losses but mainly represents some kind of redistribution of energy at later times (GAO, 1984). Both of these mechanisms have the same effect: the amplitude of a wave decreases with distance. The relative contribution of intrinsic attenuation and scattering attenuation to the total attenuation has been a subject of interest in the last years. AKI (1980) stated that scattering attenuation

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was dominant in the apparent attenuation while Frankel and Wennerberg (1987) support the opposite.

Wu (1985) proposed a method, based on the radiative transfer theory (Ishimaru, 1978) which can be applied for an estimation of the relative contribution of scattering and intrinsic attenuation, from the dependence of the total S-wave energy on hypocentral distance. This method has been applied by Wu and Aki (1988) to data from the Hindu Kush region and found that intrinsic attenuation was dominant in that region. Toksoz et al. (1988), Mayeda et al. (1991) and McSweeney et al. (1991) applied the same method to data from eastern North America, southern California and Alaska, respectively, and found that scattering attenuation was dominant.

Frankel and Wennerberg (1987) used the energy flux model of seismic coda to obtain separate estimates of scattering and intrinsic Q based on coda amplitude and decay, and they found that the coda decay is more sensitive to intrinsic attenuation.

Hoshiba et al. (1991) developed a new method based on Monte Carlo simulations of the temporal shape of the coda envelope (Hoshiba, 1991). The application of this method to data from the Kanto-Tokai region of Japan (Fehler et al., 1992) showed that intrinsic attenuation was higher than scattering attenuation for frequencies between 2 and 8 Hz and that coda wave attenuation was similar to the intrinsic attenuation in this frequency band. The same method was applied by Mayeda et al. (1992) to data from Hawaii, Long Valley and Central California. They found that for frequencies less than or equal to 6.0 Hz scattering was greater than intrinsic attenuation, while above 6.0 Hz the opposite was observed.

The present study is a first attempt to study the contributions of the intrinsic and scattering attenuation, $Q^{-1}_I$ and $Q^{-1}_s$ to the total S-wave attenuation, $Q^{-1}_t$, where

$$Q^{-1}_t = Q^{-1}_I + Q^{-1}_s$$

by applying Wu's (1985) method to local earthquake data from northern Greece. For the same region, the coda attenuation $Q^{-1}_c$, has been estimated (Hatzidimitriou, 1993) for frequencies between 1.5 and 12.0 Hz and lapse times between 10 sec and 100 sec, using the single S-to-S backscattering model of Aki and Chouet (1975). A comparison is made between the results of the present study and the coda wave attenuation.

2. Data Used

The data used in the present study originate from local earthquakes recorded by the telemetered network which is operated by the Geophysical Laboratory of the University of Thessaloniki in northern Greece. The network started its operation in