

Seismic waveform analysis in randomly heterogeneous media using sweep signal

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In most of reflection seismic explorations, people implicitly assume that the large-scale subsurface target heterogeneities are sufficiently large and strong that other background heterogeneities only cause small fluctuations to the signals from the target heterogeneity. In this case, a clear distinction can be made between target structures and the small-scale background heterogeneities. However, if the small-scale heterogeneities are significantly strong and are of comparable size to the seismic wavelength, complicated waveforms often appear. This complication causes much difficulty when investigating subsurface structures by seismic reflection. In deep crustal studies (Brown et al., 1983) or geothermal studies (Matsushima et al., 2003), seismic data often have a poor signal-to-noise ratio. Those complicated seismic waves are due to seismic wave scattering generated from the small-scale heterogeneities, which degrades seismic reflection data: attenuation and travel time fluctuations of reflected waves, and masking of reflected waves by multiple scattering events. In this case, the conventional single-scattering assumption of migration may not be applicable, i.e. multiple scattering caused by strong heterogeneities may contribute strongly to disturb energy distribution in observed seismic traces (Emmerich et al., 1993).

A detailed understanding of propagation of seismic waves in heterogeneous media has been well established by many authors on the basis of theoretical studies (Sato and Fehler, 1998), numerical studies (Frankel and Clayton, 1986; Hoshihara, 2000), and experimental studies (Nishizawa et al., 1997; Sivaji et al., 2001). Since scattered waves are incoherent and the heterogeneity is presumed to be random, the statistical properties of seismic wave fluctuation relate to the statistical properties of the random heterogeneity. Here we propose a method using sweep signals to understand velocity dispersion.