Generalized Primary Propagator Estimation from Walkaway VSP Data

Menno Dillen, Kees Wapenaar, Jeroen Goudswaard
Delft University of Technology, Section Applied Geophysics and Petrophysics

In a complex or finely layered medium one attempts to derive global wave field propagation operators, with respect to a medium description on a spatial scale, which is determinable from field data, given the temporal and spatial sampling of the measurement. The effects of fine detail are integrated in the operators by some averaging process yielding a global parametrization without requiring detailed local information. In this way, the wave field propagation operator can, for example, be defined by stochastic macro-model parameters assuming a random process for the medium fluctuations. Wave field propagation through a finely layered medium causes apparent angle-dependent attenuation and dispersion of the so-called pseudo-primary (Burridge and Chang 1989). Wapenaar and Herrmann (1993), using the term generalized primary to denote the transmitted wave field through a finely layered medium, device an inverse wave field extrapolation operator which is the adjoint of the forward generalized primary, multiplied by an operator containing the autocorrelation of the measured scattered wave field. Such a modified adjoint operator improves migration results by generating true amplitudes which are used in AVO and inversion algorithms.

A walk-away VSP data set is used as a controlled physical experiment to quantify the validity of a potential macro-model parametrization. Using the walk-away VSP configuration one has measurements of the wave field at a number of depth levels. Hence, the propagation properties from one depth level to the next can be studied. Taking into account the geometrical spreading and the first-order transmission effects, any other loss which attenuates the down-going wave field is estimated using the spectral-ratio method, which considers the amplitude ratio of the frequency domain down-going wave field at consecutive depth levels. The attenuation is quantified by the quality factor Q, which can be decomposed into a component Q^s, due to scattering losses, and a component Q^a, arising from anelastic absorption losses, according to $1/Q = 1/Q^s + 1/Q^a$. The anelastic component Q^a is a measure for the energy dissipation per cycle for sinusoidal waves. From walk-away VSP field data the total angle-dependent attenuation in terms of Q is obtained. Using an elastic layer code, Q^s is estimated for the well log at zero offset. Assuming a relation between the well log Q^s and the one for the normal-incidence, walk-away inferences can be made about the latter's Q^a.