Intrinsic and Apparent Seismic Attenuation in VSP Data

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Abstract

Seismic attenuation factors are sought because they can be useful for: amplitude recovery, improving resolution, stabilizing wavelet phase, defining lithology and perhaps providing indications of hydrocarbon saturation. We are thus interested in determining robust and accurate ways to estimate attenuation or quality factors (Q) and to use them. One technique we have employed for Q estimation is the analytic signal method. However, when applying the analytical signal method to estimate Q in some actual VSP-data, we find that it has an offset dependence.

Q-factors compensated for transmission losses are estimated in this study by computing running transmission coefficient products derived from a well-log of the Ross Lake heavy oilfield. High Q-values at shallow depths appear to be even more emphasized now. What, then, could be the cause for these over-estimated Q-values? The Q-factors estimated here are apparent Q, which is a combination of the desired intrinsic Q of the rock layers, the stratigraphic Q caused by reverberations between layer interfaces, and a gain component. When comparing results from a 1D wave equation model to the running transmission coefficient product, a good match is observed. 1D scattering, though present in this case, is not a major contributor to apparent attenuation.

Because offset dependence is observed, a 2D model seems more appropriate in this case. We have adapted a 2D elastic wave equation method (Virieux, 1986) to the VSP case. Both P- and S_v -source VSP sections have been computed. A great richness of wave types and complications are generated. For non-zero offset cases, these synthetic VSP's show multiples and multimodes on reflection and transmission. At small source offsets, trace maxima of instantaneous amplitudes decay quite smoothly with depth because of 2D spreading in this model case. At large offsets, however, significant depth regions of instantaneous amplitude increases are observed. This stratigraphic "amplification" is one possible explanation for the peaking of shallow depth Q-estimates from actual VSP data.