Analysis and correction of seismic transmission losses due to thin-layering in North Sea formations [*]

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Summary

A very detailed and carefully blocked model of the reservoir zones is used for AVO modelling or inversion. In contrast to the reservoir area, the overburden of the target horizons is usually replaced by a coarsly blocked version of the well log data or by a macro-velocity model. Fluctuations on smaller scales are neglected. We studied the angle-dependent transmission loss due to such fluctuations for two geological formations in the North Sea. Modelling results for blocked log data which neglect the fluctuations were compared with results for the corresponding thinly-layered models. Significant thin-layering effects could be observed for the Hordaland group. Similiar effects, although less in magnitude, were obtained for the deeper Shetland group. It has been clearly shown that elastic modelling based on a coarsly blocked log of the overburden neglects those effects of angle dependent scattering losses.

We recently introduced the application of the generalized O'Doherty-Anstey formula (Shapiro and Hubral, 1996) in an AVO processing scheme to take thin-layering effects into account (Widmaier et al., 1995). Here, the correction was applied to remove such scattering attenuation effects according to 1D models of the Hordaland and Shetland group. The method worked well in all studies, especially when the offset behaviour of the normalized amplitudes was considered.

Principles

For the Hordaland and Shetland group complete v_p, v_s and density log data sets were available at the chosen well location. We blocked both into approximately 20 layers (non-uniform thickness) per 1000 m depth intervall. The log data for each formation was seperated from the complete well log and embedded inbetween two homogeneous layers (Figure 1). An artificial, isolated target horizon was introduced below the thin layers. For each geological formation two different shot records were calculated. The first one is based on the blocked log, the second one on the log with the original sample increment. Conventional AVO processing of CMP gathers was performed. The scaled AVO target responses of the blocked and the thinly-layered model were compared with their respective Zöppritz curve. It can be observed, that the offset-dependence of the target reponse is not effected significantly by the propagation through the coarsly blocked model. The scaled measured amplitude and the exact reflectivity coincide. But for the thinly-layered model of the Hordaland group the scaled amplitudes remain too low at larger offsets (Figure 2, left). The relative, normalized amplitude error increases up to 10 %. Obviously, the amplitudes have been attenuated by the thinly-layered overburden. All offset-dependent influences seem to have their origin in the fluctuations of the overburden model.

To describe thin-layering effects by the generalized O'Doherty-Anstey formula the log data has to be seperated into a macro-velocity model and a macro-statistical model. The macro-statistical model describes the fluctuations in v_p, v_s and ρ. We followed the experiences we made with synthetic, non-stationary logs. Those are discussed in a related abstract (Knoth et al., 1996). In order to isolate the fluctuations we defined the blocked model as the background trend and subtracted it from the original well log data. Exponential functions were fitted by a least square algorithm to the auto- and crosscorrelations of the residual fluctuations and statistical parameters were derived. Then, an effective, offset-dependent scattering coefficient was calculated using the generalized O'Doherty-Anstey formula. By inverse filtering with the scattering coefficient the thin-layering distorted AVO response could be corrected successfully (Figure 2, right).

If simple Q-compensation of real data (or inelastic modelling) accounts sufficiently for thin-layering effects has to be investigated in future. Fact is, that the relative offset-dependent amplitude loss predicted by the generalized O'Doherty-Anstey formula and observed in the models is higher than the absorption loss for an equivalent inelastic model with a constant Q assumption. But on the other hand, the magnitude of scattering attenuation is in general much lower than the absorption measured in zero-offset VSP-data.

Acknowledgements

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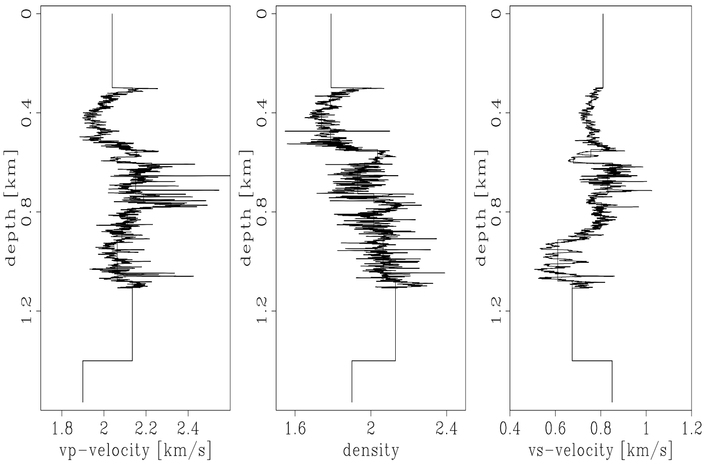

Figure 1: Depth-shifted log intervall of the Hordaland group: The homogeneous parts below and above the formation and the target horizon were introduced artificially.

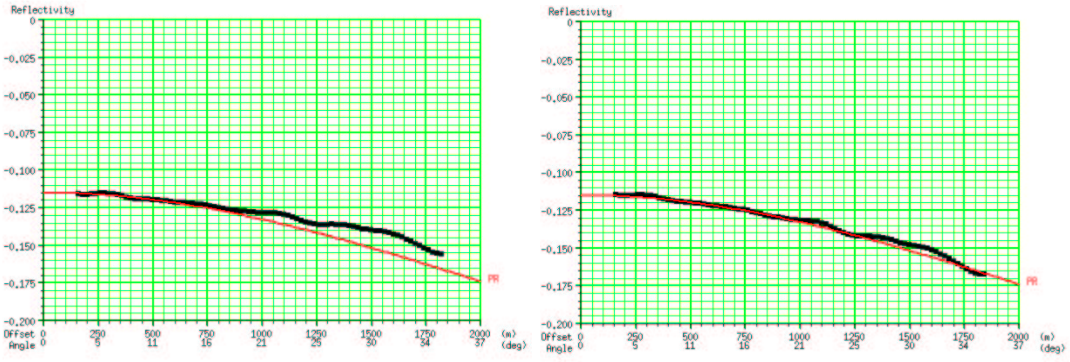

Figure 2: AVO response for the thinly-layered Hordaland model compared with the Zöppritz curve before (left) and after thin-layering correction (right). The amplitudes are normalized within the near offset range.