AVO analysis of thin layers: Application to CO_2 storage at Sleipner

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Introduction

We present an application of model based AVO to a case of thin layer reflections at Sleipner. We apply this method to analyze the top most reflection from a series of reflections that are interpreted to be several thin CO_2 layers accumulating under intra-reservoir mudstone layers; and/or multiples within the layers. The objective is to estimate the thickness of the CO_2 layer.

The method: Model based, optimised AVO

1. Define a reflector class model
2. Forward model (realistic) reflection coefficients *R(θ)*
3. Approximate *R(θ)* via singular value decomposition:
   $R(\theta) \approx C_1 f_1(\theta) + C_2 f_2(\theta) + C_3 f_3(\theta)$
4. Crossplot coefficients C_1 and C_2 of model and real data

Model building

1. Definition model geometry at Sleipner:

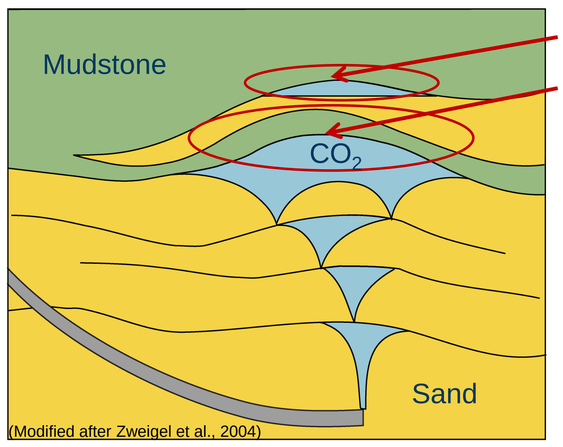


Figure 1:
The injected CO_2 at Sleipner accumulates in thin layers under intra-reservoir mudstone layers. We model the two illustrated cases (red circles)

2. Estimation of seismic properties:

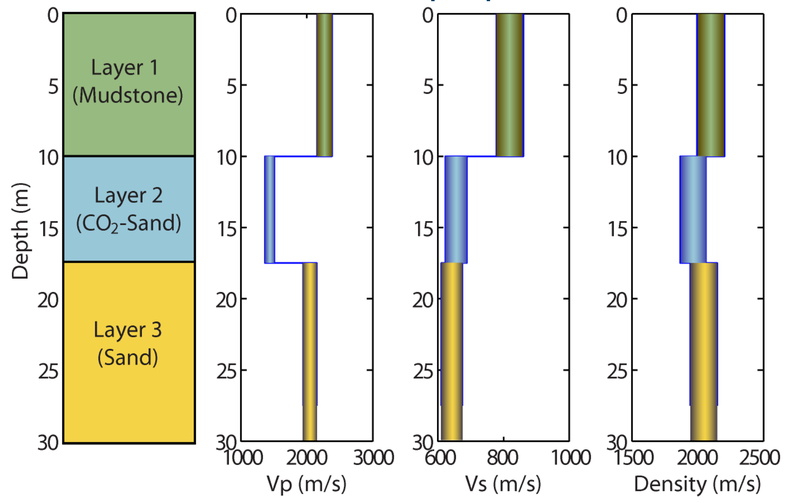
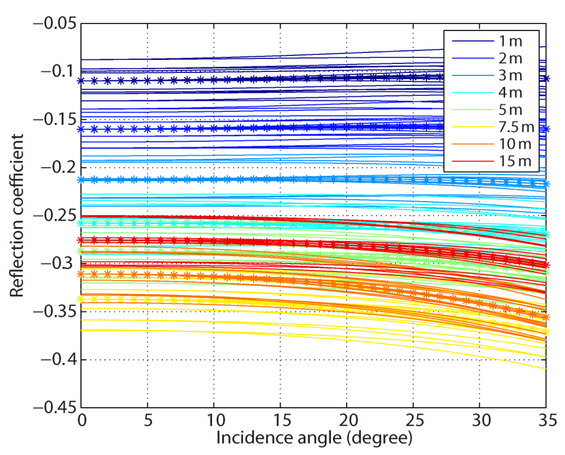


Figure 2:
Model (corresponding to Model 1 in Fig. 1) and seismic property ranges for CO_2 collecting underneath a 6-m thick shale layer. The seismic properties are obtained from well-logs, CO_2-saturation profiles, thermo-dynamic equations, and rock physics models. A 5% variation in all parameters accounts for uncertainty and natural variation.

Reflection coefficients and C_1-C_2 crossplots



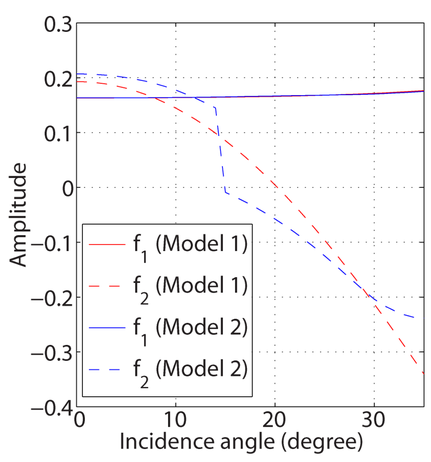
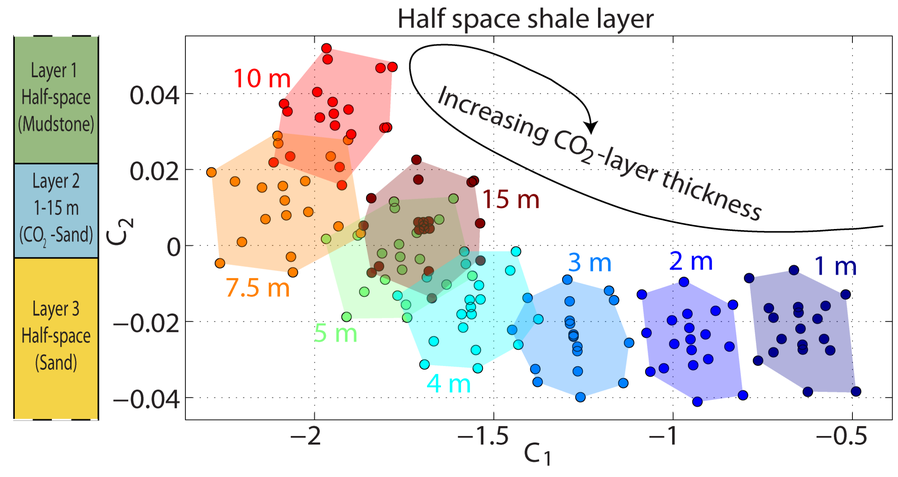


Figure 3: Basis functions after SVD of R(θ) in Fig. 1

Figure 3: Reflection coefficients for various CO_2-layer thicknesses in Model 1 (color-coded). The dotted lines correspond to zero-variation, the other ones to 5%-varied seismic properties.



!!! A clear trend with increasing CO_2-layer thickness !!!
!!! But overlapping due to natural variation !!!

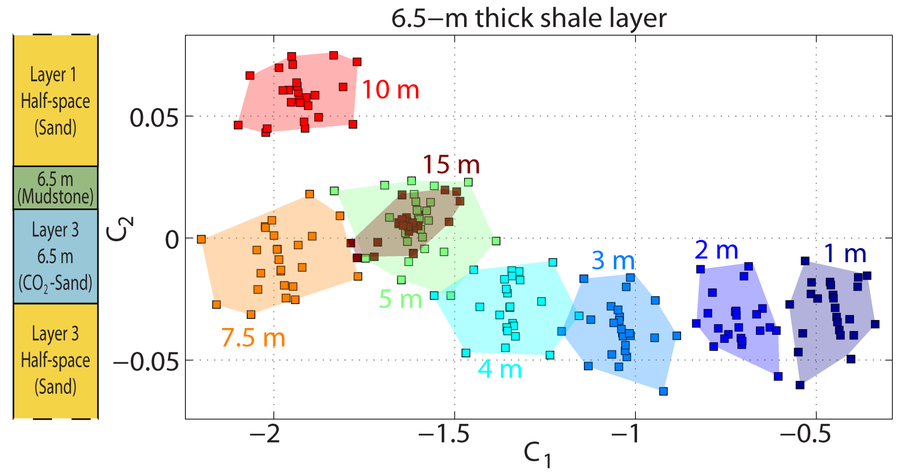


Figure 4:
Crossplot of corres-ponding C_1-C_2 coefficients for Model 1 (top) and 2 (bottom).
The effect of the CO_2-layer thickness is bigger than that of a 5% variation in the seismic properties, but an overlap occurs. Notice that the C_1-C_2-coefficient areas for each thickness are not necessarily different for the two models.

Application to real data

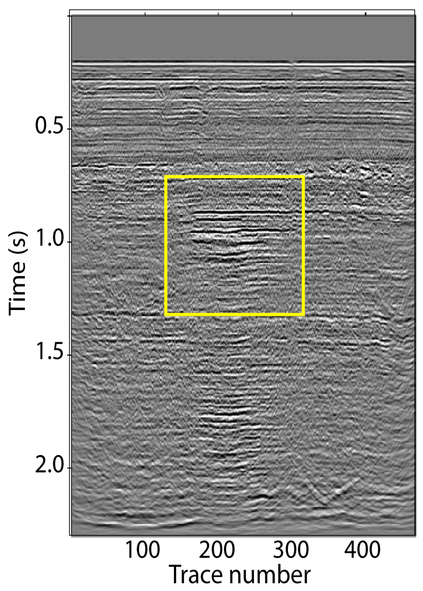


Figure 5: Near-offset data for a line across the Sleipner plume (yellow box).

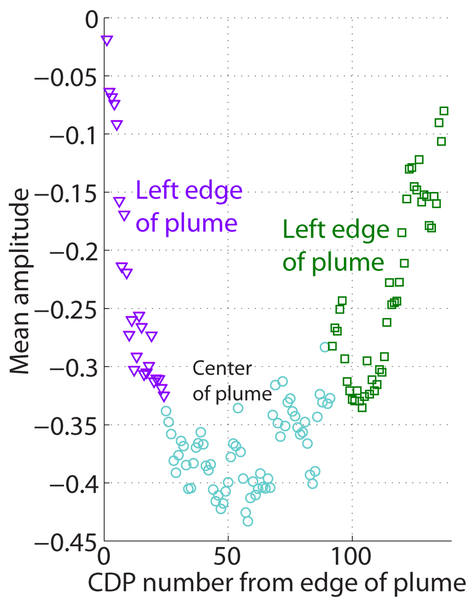


Figure 6: Mean amplitude for the top most reflector for every CDP gather. The color-code defines the position in the plume (edge or center)

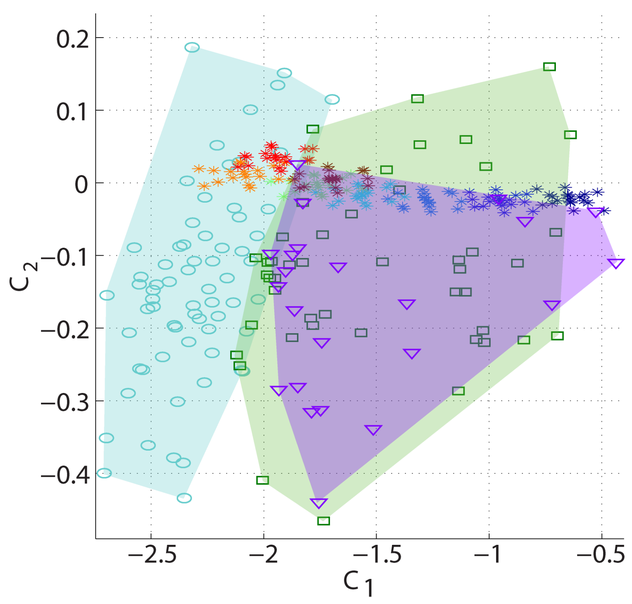


Figure 7: Crossplot of C_1-C_2 coefficients of data and Model 1. The data coefficients are obtained by optimally fitting data to the basis functions obtained from Model 1 (Fig. 3). The color-code is the same as in Fig. 6. Also shown are the coefficients of the modeled data.

Conclusion

The real data coefficients show the same trend of the modeled data: Data from the center of the plume, where the CO_2 layer supposedly is thickest, plot further left, than those from the edges, where the CO_2 layer is expected to thin-out. However, the real data show considerably more spread. Classification into layer thicknesses would be coarse due overlapping coefficients.

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