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Full waveform seismic modelling of Chalk Group rocks from the Danish North Sea – implications for velocity analysis

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This study aims at understanding seismic wave propagation in the fine-layered Chalk Group, which constitutes the main reservoir for oil and gas production in the Danish North Sea. The starting point of our analysis is the Nana-1XP exploration well, which shows strong seismic contrasts inside the Chalk Group.
For the purposes of seismic waveform modelling, we here assume a one-dimensional model with homogeneous and isotropic layers designed to capture the main fluctuations in petrophysical properties observed in the well logs. The model is representative of the stratigraphic sequences of the area and it illustrates highly contrasting properties of the Chalk Group. Finite-difference (FD) full wave technique, both acoustic and elastic equations are applied to the model.
Velocity analysis of seismic data is a crucial step for stacking, multiple suppression, migration, and depth conversion of the seismic record. Semblance analysis of the synthetic seismic records shows strong amplitude peaks outside the expected range for the time interval representing the Chalk Group, especially at the base. The various synthetic results illustrate the occurrence and the impact of different types of waves including multiples, converted waves and refracted waves. The interference of these different wave types with the primary reflections can explain the strong anomalous amplitudes in the semblance plot. In particular, the effect of strongly contrasting thin beds plays an important role in the generation of the high anomalous amplitude values. If these anomalous amplitudes are used to pick the velocities, it would impede proper stacking of the data and may result in sub-optimal migration and depth conversion. Consequently this may lead to erroneous or sub-optimal seismic images of the Chalk Group and the underlying layers.
Our results highlight the importance of detailed velocity analysis and proper picking of velocity functions in the Chalk Group intervals. We show that application of standard front mutes in the mid- and far-offset ranges does not significantly improve the results of the standard semblance analysis. These synthetic modelling results could be used as starting points for defining optimized processing flows for the seismic data sets acquired in the study area with the aim of improving the imaging of the Chalk Group.