Seismic-dependent Facies and Porosity Modeling of the Rotliegend Gas Field
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Summary

3-D acoustic impedance, facies, and reservoir property models were built to aid the reevaluation and development of the Upper Permian Rotliegend Gas Field in northwestern Germany. 3-D facies model was built using the facies (lithotype) logs, constrained by the calibration between the facies and impedance data, and the stochastic inversion impedance volume. Utilization of the impedance data was of critical importance to construct realistic facies model because of the sparse well control in the study area. Facies-constrained 3-D porosity models using the sequential Gaussian simulation technique were created using the well data as hard data.

Introduction

This study built high-resolution 3-D acoustic impedance, facies, and reservoir property models to facilitate the reevaluation and well planning of the Rotliegend Gas Field.

The reservoir modeling in this study was accomplished in three stages: a) building a facies model based on facies proportion curves from histograms of facies-based acoustic impedance data; b) creating porosity models constrained by facies model; and, c) constructing permeability models using the porosity-permeability cloud transform. The seismic inversion and reservoir modeling in this study were performed using (RC)2 software.

The two main producing zones of the Rotliegend Gas Field are the Wustrow and Ebstorf members of the Hannover Formation, composed of interbedded sand-shale sequence, situated at the depths from 4500 m to 5000 m. The Wustrow member, containing a thick shoreline sandstone unit, is the primary gas reservoir in this field. The reservoir quality in the Rotliegend Gas Field is governed primarily by the diagenetic alteration of the sandstones (Hock et al., 1995) including cementation of the primary pore spaces by illite, kaolinite, quartz and calcite. The Rotliegend reservoirs, sourced by the deep-seated carboniferous coal formation, are sealed at the top by the overlying Zechstein salt formation.

Input Data

The facies, impedance, porosity and permeability logs, and time and depth markers from 35 wells, the stochastic inversion impedance volume, and the time and depth surfaces were used in the reservoir property modeling of the Rotliegend Gas Field. Figure 1 shows the area of interest (AOI) and the wells, along with the 3-D seismic coverage.

Figure 1. Base map displaying the wells and 3-D seismic coverage.

Impedance-dependent Facies Modeling

The lithotypes in the study area consists of shoreline sand (A), illite-coated sand (B), aeolian sand (C), mudstones (D), fanglomerates (E), and anhydrite, carbonates and volcanics (F). These lithotypes will hereafter be referred to as Facies A through F.

The generalized workflow for facies modeling using sequential indicator simulation (SIS) with local proportions comprises steps of extracting facies fractions for the reservoir zones, modeling the areal and vertical variograms, generating facies-based impedance histograms, building facies proportion curves, snapping stochastic inversion data to the depth grid, and constructing facies model using sequence indicator simulation with local proportions algorithm.

Facies fractions were estimated to obtain the fractional proportion of each facies in the Wustrow, Ebstorf and Dethlingen reservoir intervals.

The areal (directional) and vertical facies variograms were modeled from spatial continuity analysis using facies logs.

Figure 2 displays the impedance histograms for Facies A, B, C, and D in the Wustrow interval. The histograms
shown in Figure 2 were first normalized and then combined into facies proportion curves (Lo and Bashore, 1999) for the Wustrow interval, as illustrated in Figure 3. The vertical and horizontal axes in this diagram represent the facies probability and impedance, respectively. The facies calibration proportion diagrams for the Ebstorf and Dethlingen intervals were generated in the same manner.

The acoustic impedance volume produced from stochastic seismic inversion (Shrestha and Boeckmann, 2002) were snapped to the depth grid and used for calibration in facies modeling. Figure 4 displays results of stochastic inversion at line 1202. The impedance models representing the Wustrow, Ebstorf and Dethlingen intervals, when calibrated with the impedance logs at well locations, showed excellent correlation.

Sequential indicator simulation (SIS) (Journel and Alabert, 1988; Xu et al., 1992) with local proportions using the facies logs as hard data and the facies proportion curves as soft data produced the facies model. The facies proportion curves were tied to the acoustic impedance volume through facies calibration (Lo and Bashore, 1999). Facies models for the Wustrow, Ebstorf, and Dethlingen intervals were built separately and were subsequently combined into a single model using a framework including all three zones. Figure 5 depicts the simulated 3-D facies model including the three reservoir intervals.

Conclusions

Use of the high-resolution acoustic impedance volume from stochastic modeling as a soft data constraint in building 3-D facies (lithotype) model is of critical importance because of sparse well control in the Rotliegend Gas Field. The facies model characterizes a group of rocks with similar petrophysical and fluid properties. The facies model also permits distinction between reservoir and non-reservoir rocks.

3-D porosity models created by employing a facies-to-property approach are more realistic because these models account for varying spatial continuity in different facies. In addition, such models preserve the facies-specific statistical distribution of porosity. Therefore, the facies-based porosity models contributed to improved prediction of porosity distribution and reservoir heterogeneity to facilitate the development of the Rotliegend Gas Field.

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References


Figure 2. Impedance histograms for Facies A, B, C and D of the Wustrow interval.

Figure 3. Facies versus impedance calibration diagram for the Wustrow interval.

Figure 4. Results of stochastic inversion at line 1202 with the Well A impedance log overlay.
Figure 5. 3-D representation of simulated facies A through F (vertical exaggeration 20 times).

Figure 6. 3-D representation of simulated porosity based on the first realization (vertical exaggeration 20 times).