Characterization of high-amplitude seismic anomalies in the Hoop Fault Complex, Barents Sea

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Introduction

Many areas of the western Barents Sea host shallow as well as deep-seated hydrocarbon accumulations, wherefrom fluids are migrating to the sea floor. Evidence of past episodes of gas migration can be seen in the form of pockmarks on the sea floor as well as vertical pipes or chimneys on seismic sections. Natural gas hydrates are also present in some areas and free gas is present below the base of the hydrate stability layer that is typically shallow. Such shallow migrating hydrocarbon fluids as well as free gas below the hydrates represent potential hazards for drilling deeper wells as well as the construction of sea bed installations. Thus, the detailed distribution of shallow migrating fluids or the presence of gas in the shallow zones in the areas under investigation is required, for which data with high vertical and spatial resolution is required.

Case study at hand and workflow

A portion (500 sq. km.) of the 3D seismic volume covering over 22,000 sq. km. in and around the Hoop Fault Complex in the Barents Sea, was picked up for carrying out a feasibility analysis aimed at characterizing the bright seismic amplitude anomalies, and also examining the fault and channel features in detail. But for the present exercise, the objectives were to look for potential reservoir leads within the Stø (Mid-Jurassic) and Kobbe (Mid-Triassic) formations, detect the potential prospects associated with direct hydrocarbon indicators (DHIs), and study the areal extent of the potential reservoirs and how they are impacted by the fault configurations present in the interval of interest.

Discriminating seismic anomalies associated with the presence of hydrocarbons from those that are not could be challenging. But it is important that such challenges are addressed so as to prevent costly drilling failures. A straightforward choice for accomplishing this would be to put the data through impedance inversion (so that pockets of low-impedance/density, indicative of hydrocarbons or high porosity can be picked up) and also generate one or more discontinuity attributes such as coherence and curvature, so that the definitions of the channels and faults stand out clearly. Thus, by adopting a workflow that entails the generation of P-impedance, S-impedance and density attributes and examining these or other derived attributes in crossplot space, it is possible to identify the fluid-associated anomalies. This analysis was supplemented further with the generation of rock physics templates constructed from well log data for generation of trends for different lithologies and fluids that may be expected in the area. Once these are generated, they are used as an aid or guide for interpretation of elastic inversion-derived attributes.

But when it comes to the determination of petrophysical properties such as water saturation, effective porosity and permeability, an extension of the elastic impedance approach, called *extended elastic impedance* is utilized. The basic idea behind this workflow is that though typically the incident angle range is 0 to 30^{o}, it can be mathematically extended to a greater angle range, and by modifying the

Zoeppritz formulation, extended elastic impedance reflectivities at different angles can be generated. By cross-correlating these generated reflectivities with the desired petrophysical property, the optimum angle can be determined, which can then be used to derive the desired petrophysical property from seismic data. As we cross-correlate the extended elastic impedance reflectivities with the desirable V_{clay} and effective porosity log curves for different values of the angles, we plot the correlation coefficients as a function of the angle of incidence. The maximum positive correlation coefficient of 0.85 for V_{clay} (blue curve) is seen at 28^o, while effective porosity exhibits a negative correlation coefficient of 0.9 at angle 22^o (green curve). These values of angle enable the determination of these properties from seismic data through the application of Zoeppritz equations.

Once the effective porosity and V_{clay} volumes are derived they are correlated with the respective petrophysical log curves. A reasonably good match between them was seen in both cases, which enhanced our confidence in the application of the followed approach for the data at hand.

Conclusions

In conclusion, we characterized the direct hydrocarbon anomalies that we detected through the application of spectral decomposition, with more detailed analysis employing extended elastic impedance for deriving effective porosity and volume of clay from seismic data. The good correlation of these volumes with the available respective petrophysical well log curves enhanced our confidence in their interpretation.