GCCharacterizing Shallow Seismic Anomalies*

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General Statement

Many areas of the western Barents Sea host shallow as well as deep-seated hydrocarbon accumulations from which 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, which 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.

A portion (500 square kilometers) of the 3-D seismic volume covering over 22,000 square kilometers in and around the Hoop Fault Complex (Figure 1) 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. For the present exercise, the objectives were to look for potential reservoir leads within the Stø (Mid-Jurassic) and Kobbe (Mid-Triassic) formations (Figure 2), 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.

A cursory examination of the 3-D seismic volume (by way of vertical and horizontal sections) reveals bright amplitude anomalies in the shallow intervals, interspersed with many discontinuities interpreted as faults (Figure 3). Most of the bright amplitude anomalies appear to be coming from channels that show up well on the horizontal displays (time or horizon slices).

There may be several reasons for an amplitude anomaly to show up on seismic data. Besides seismic processing artifacts, a clean, high-porosity wet sand, tight sand, low-saturation gas sand or a lateral change in lithology could exhibit a high amplitude anomaly. Similarly, streaks of salt, volcanics, or carbonates could indicate anomalies. Needless to mention, a combination of one or more of the above-stated geologic conditions could exhibit false amplitude anomalies. Processing of seismic data in an amplitude-friendly way and gaining a good knowledge about the geology of the area under investigation, together with the expected seismic response through modeling are established ways of lowering the uncertainty in the analysis.

Distinguishing seismic anomalies associated with the presence of hydrocarbons from those that are not could be challenging. But it is important that such challenges be addressed so as to prevent costly drilling failures.

A straightforward choice for accomplishing this would be to put the data through impedance inversion (so 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.

Spectral Decomposition Application

It is always instructive to carry out alternative workflows with different tools and compare the results for assessing the uncertainty in the exercise. Keeping in line with this strategy, we explore the application of spectral decomposition to the data at hand. The decomposition of the seismic signal band into constituent frequencies is referred to as spectral decomposition. It is a useful tool that has important applications including differentiation of lateral and vertical lithologic and/or pore-fluid changes as a DHI indicator, and seismic geomorphological applications aimed at delineating stratigraphic traps. For more details, the readers are encouraged to look through the following articles:

Spectral Decomposition’s Analytical Value, Search and Discovery Article #41260.

Spectral Decomposition Helps Define Channel Morphology, Search and Discovery Article #41272.

Effective Ways to Eliminate Side-Lobe Effects, Search and Discovery Article #41273.

Spectral Decomposition Methods: Applicability and Limitations, Search and Discovery Article #41323.

Enhancement of Multicomponent Seismic Data, Search and Discovery Article #41778.

In the context of DHIs, the basic premise is that reflections from fluid-saturated rocks are frequency-dependent. It is well known that such reflection coefficient (water/gas) ratios are three times stronger at 14 Hz than at 50 Hz, and thus the observed reflection amplitudes can be used for detecting liquid-saturated areas in thin-porous layers. In the presence of hydrocarbons, the encasing formations selectively reflect some particular frequencies and not others, leading to high amplitudes on seismic sections. This is due to the fact that higher frequencies suffer higher attenuation while traversing hydrocarbon reservoirs. In the event the reservoirs are thin, the tuning of reflections also exacerbates the amplitude responses from reservoirs. It has been demonstrated in the geophysical literature that the instantaneous spectral analysis of seismic data shows low-frequency modes of the seismic wave-field providing more useful information for the study of fluid-saturated rocks.

We used the matching pursuit method of spectral decomposition on the data at hand and noticed that many of the high amplitude anomalies are associated with higher spectral amplitudes. In Figure 3a we show a segment of inline from the input seismic volume showing some high amplitude anomalies. We plot the equivalent spectral magnitude displays at 20 Hz and 60 Hz and are shown in Figures 3b and 3c. Notice the high spectral magnitude values seen at 20 Hz, but not on the 60 Hz display, even though the bandwidth of the data extends to above 80 Hz. We do not claim that this analysis is conclusive, but it is a method for direct detection of hydrocarbons, and can be taken forward for confirmation.

Conclusions

Besides improving the quality of the existing seismic data through reprocessing (with the latest algorithms) and their integration with borehole data, the state-of-the-art acquisition of fresh data with more powerful acquisition technology are being carried out in the Barents Sea. In order to improve the quality of the data being used for interpretation and analysis as well as effectively de-risk the prospects ahead of drilling, the state-of-the-art technology is being used for its collection. Besides this, diverse data types, both geological and geophysical, are being brought together so as to come up with an integrated assessment for the prospects. Multibeam seafloor mapping and sampling is also being done by some of the operators in that area. Plans are also under way for integrating all this data for mitigating exploration risk.

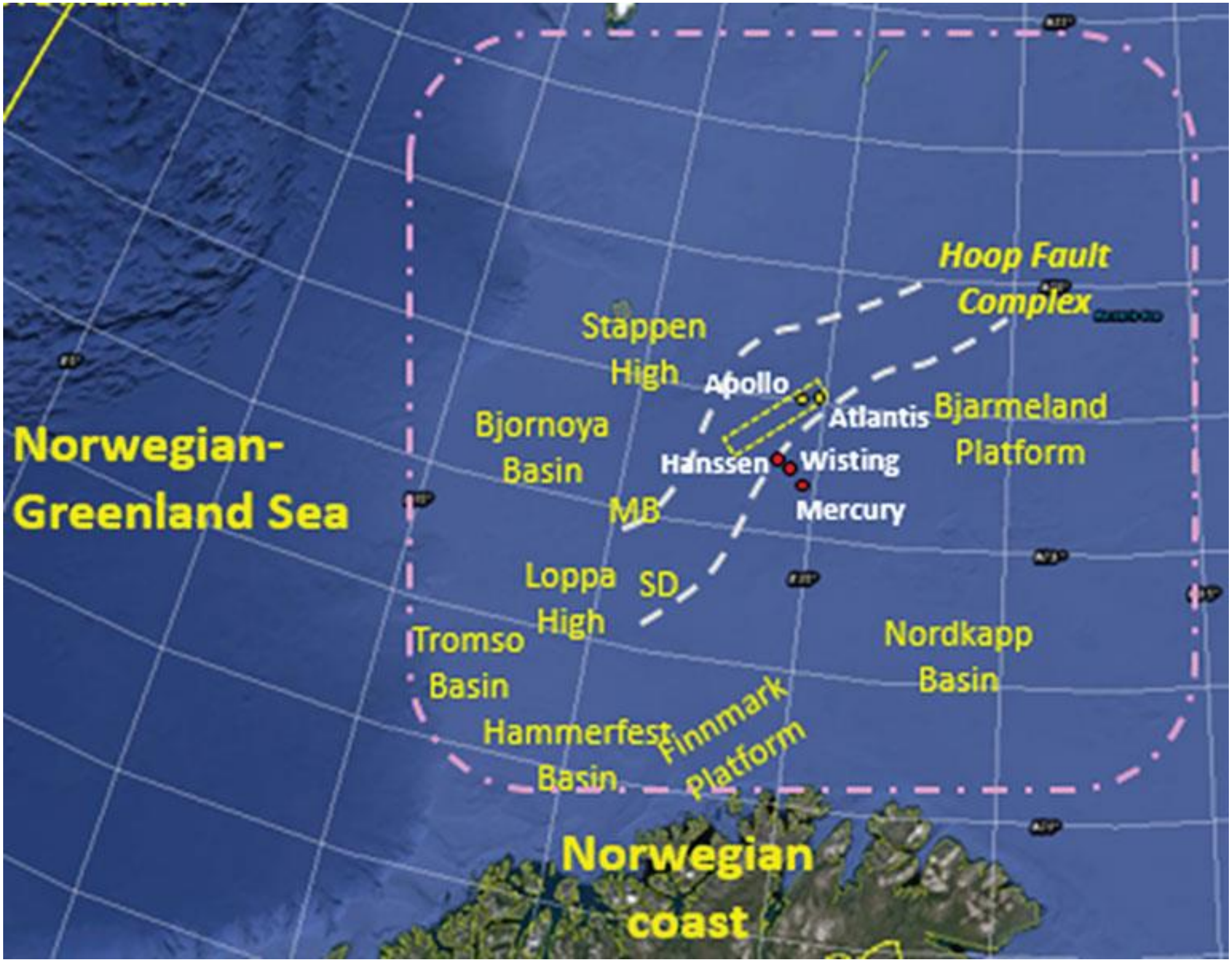

Figure 1: Location map showing the western Barents Sea and some of the some of the structural elements in that area. The corridor in white thick dashed lines shows the Hoop Fault system running roughly in a NE-SW direction. The location of the seismic data volume that was picked up for the present study is shown with the yellow dashed rectangle, and falls within the Hoop Fault corridor. The drilled wells are marked in white. Abbreviations: SD - Svalis Dome; MB - Maud Basin. (Image generated using Google Earth).

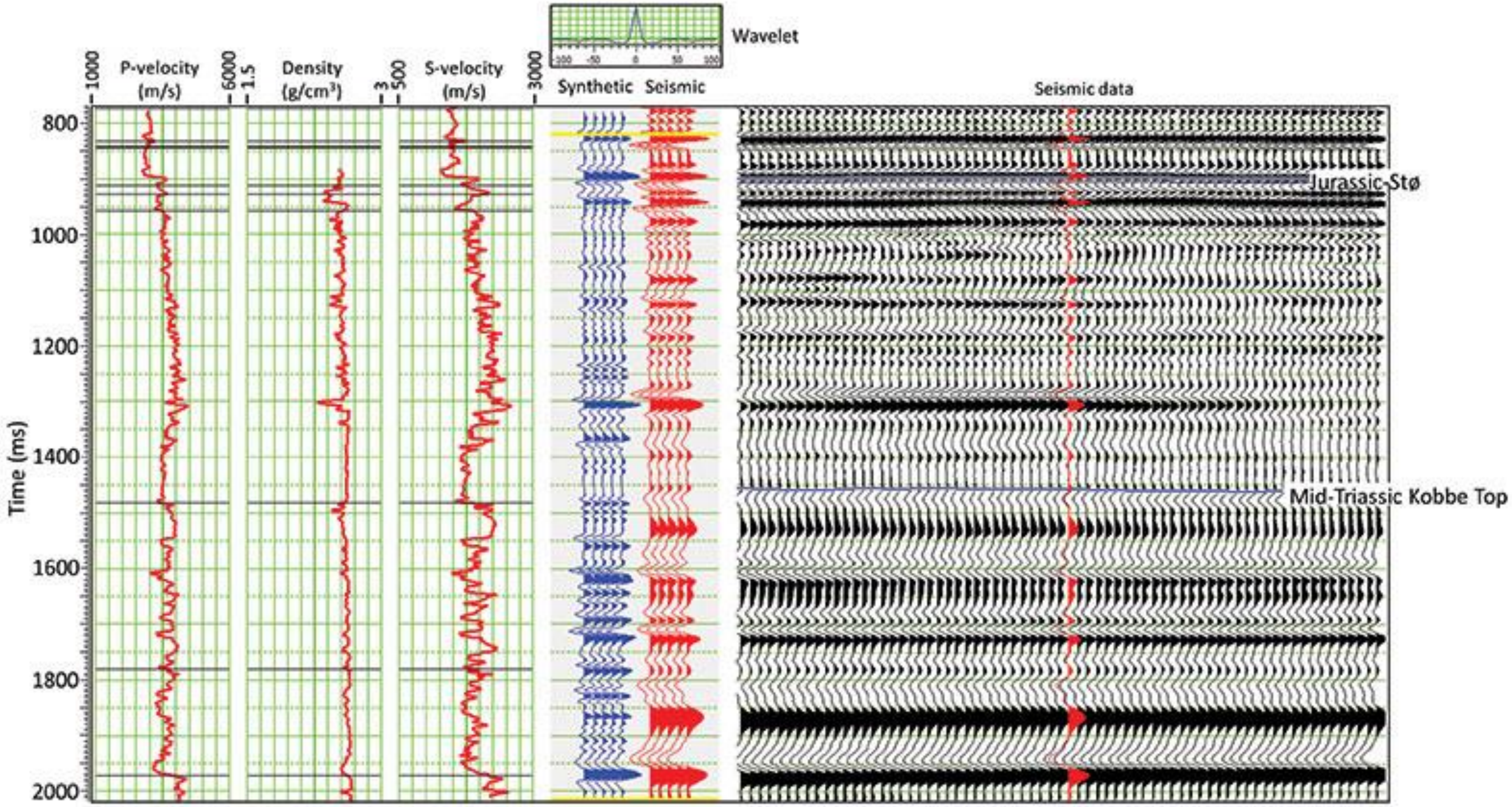

Figure 2: Well-to-seismic tie for Atlantis well. The wavelet extracted from the seismic data is shown above. The traces in blue are the modeled traces and the seismic traces at the location of the well are in red.

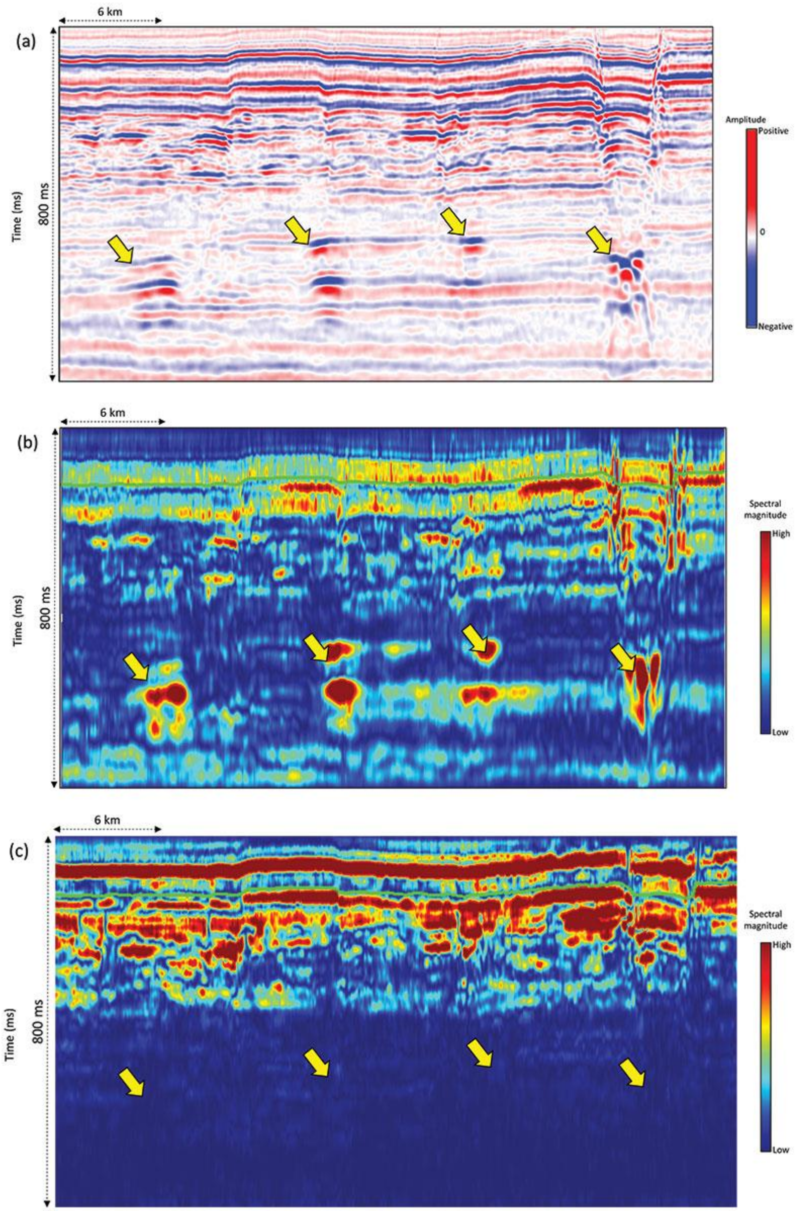

Figure 3: (a) Segment of an inline showing high amplitude anomalies. The display contrast has been reduced so as to depict these anomalies clearly. The equivalent segments of the same inline extracted from the 20 Hz and 60 Hz volumes generated using matching pursuit spectral decomposition, are shown in (b) and (c) respectively. Notice the anomalies indicated with yellow arrows exhibit high spectral magnitudes on the 20 Hz section and not on the 60 Hz section. (Data courtesy of TGS, Asker, Norway.)