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A Multi-Measurement Integration Case Study from West Loppa Area in the Barents Sea

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SUMMARY

The continental shelf of the Barents Sea is one of the less known but more promising "new" basins on Earth. Seismic investigations give clear indication of at least two active petroleum systems in the region, while resistive anomalies concentrated in certain portions of the sedimentary sequences could indicate the presence of hydrocarbon fluids. In this paper, these two aspects are analyzed in an integrated way on a high resistive and seismic anomaly present in Cretaceous to Oligocene sediments. Multi-measurement integration allows a more precise definition of geologic features that, considered separately, have a level of uncertainty higher than the one observed when the same features are considered integrating different models coming from different methodologies. This is fundamental in individuating and derisking potential prospects.
Introduction

The continental shelf of the Barents Sea represents one of the most interesting frontier areas for hydrocarbon exploration and production. In this paper we present a case study where the integration of 3D seismic data and non-seismic Controlled Source Electromagnetic (CSEM) data acquired in the Northwest Loppa area (Figure 1) helps in identifying and derisking potential prospects.

Seismic investigations give clear indication of at least two active petroleum systems in the region, while resistive anomalies concentrated in certain portions of sedimentary sequences could indicate the presence of hydrocarbon fluids - which normally increase the bulk resistivity of a rock. In this paper, these two aspects are analyzed in an integrated way on a high resistive and seismic anomaly present in Cretaceous to Oligocene sedimentary sequence.

Figure 1 Location of the study area within the West Loppa survey.

Exploration and production activities in the Barents Sea increased since Statoil obtained the exploitation permissions for its Jurassic Snohvit gas field from the Norwegian government in 2001. From that moment onwards, several oil companies planned operations, data acquisitions and explorations in the Barents Sea. To better estimate the actual play potential of the entire area and consequently its economic viability, further geophysical and geologic studies are needed especially for prospects located in post-BCU clastic sediments, typically less known but potentially equally productive than the Jurassic-Triassic ones.

Starting from 2008, WesternGeco acquired and processed Multi Client high resolution 3D seismic data in the Barents Sea. On the electromagnetic side, EMGS extensively acquired 3D CSEM data in the same area, including them in their Multi Client library. In the framework of a collaborative joint agreement between the two companies, parts of the 3D CSEM data acquired in the West Loppa area have been processed and inverted in 2012 in the WesternGeco Integrated EM Center of Excellence, Milan. EMGS inverted its own data as well and the resulting models are very similar, confirming the presence of strong resistive features of interesting nature both in the Triassic-Jurassic sequence and in the Cretaceous sediments. In this paper, we focus on the Cretaceous anomaly.

Geologic setting and method

From the geologic point of view, the Barents Sea is an intracratonic basin bounded by two young passive margins to the West and to the North, developed in response to the Cenozoic opening of the Norwegian-Greenland Sea and the Eurasian basin respectively (e.g. Faleide et al. 1993). Its southwestern part, in particular, contains some of the deepest sedimentary basins on Earth, reaching depths of several kilometers and formed as consequence of several deformation events involving the North Atlantic and Arctic region (see Figure 2 for a present-day regional tectonic setting).
The main event was the Early Tertiary crustal breakup that allowed the separation of Eurasia and Greenland, and accretion of oceanic crust. At that time, two mega-lineaments were present in the southwestern Barents Sea: the North Atlantic rift and the De Geer shear zone (e.g. Faleide et al. 1993), this latter possibly continuing into the Arctic Ocean along the Greenland and Canadian continental margin. Late Mesozoic-Cenozoic evolution of the study area in tectonic rift-shear sense is well documented in many papers (e.g. Brekke and Riis, 1987), while late tectonic evolution of the southwestern Barents Sea is less known and documented in literature. Cenozoic compressional structures along the northeastern Atlantic margin have been documented in Doré and Lundin, 1996 while their impact on hydrocarbon exploration after Late Cenozoic uplift and erosion is the subject of the study made by Doré and Jensen, 1996. In the past two years, major Skrugard, Norvarg and Havis discoveries have been made by Statoil and Total, and application and potential of CSEM technology on these discoveries has been well documented in Fanavoll et al. 2012. Hydrocarbon occurrence in Cretaceous sequences is documented on the top of many Jurassic plays (e.g. Seldal, 2005) but their amount has always been considered too low and therefore their exploitation judged economically disadvantageous by the oil companies.

From the methodological point of view, the acquisition of marine CSEM data was performed deploying a series of receivers on the seafloor. The receivers measure both, the horizontal electric and magnetic field components. A transmitter towed by a vessel 30m above the mud line illuminates the receivers. The transmitter is a horizontal electric dipole that transmits a square-wave like signal with energy in the frequency range 0.1-10 Hz. EM Fields measured by the receivers are dominated by a signal that has followed diffusion into the seafloor and through subsurface. The signal is therefore carrying information about the resistivity structure at depth. The recorded fields are processed into the frequency domain, obtaining Amplitude vs Offset and Phase vs Offset data. Finally, the frequency domain data is inverted in order to obtain an anisotropic 3D resistivity model of the subsurface.

Results

Seismic processing generated a 3D seismic cube that shows two types of features of interest: 1) several flat spots distributed at variable depths but all within the older Triassic-Jurassic sedimentary sequence, and 2) a bright amplitude anomaly in the younger Cretaceous turbiditic sedimentary sequence (Figure 4). In addition, DHIs are present both in the Cretaceous and in the shallower near-surface sedimentary sequence (see Figure 3 as example). All these features are the indication that at least two petroleum systems could be currently in place in the area, one before the Base Cretaceous Unconformity (BCU) charging the older reservoirs (i.e. the flat spots) and one after, possibly affecting the Cretaceous sedimentary system and indicated by the amplitude anomaly.
Figure 3 Cross line and inline from the 3D seismic cube. Note the gas escape directly above the normal fault, indication of active petroleum systems. Data courtesy of WesternGeco.

CSEM inversion done by both WesternGeco and EMGS gave very similar results. Both the flat spots in the Mesozoic sequence and the amplitude anomaly in the Cretaceous sediments are characterized by a resistivity anomaly (see Figure 4 for the Cretaceous sequence) that indicates a change from a "normal" conductive behaviour to an anomalous resistive behaviour. In the case of the present study, the co-rendering of CSEM inversion results with the equivalent section sliced from the seismic cube highlighting RMS values on Cretaceous sediments gives additional information about the nature of that resistive anomaly – and conversely, about the nature of those seismic RMS amplitude anomaly (Fig. 4).

Figure 4 CSEM inversion results (WesternGeco version) on the younger Cretaceous anomaly co-rendered with seismics in 3D view (A), with depth iso-lines in map view (B), with RMS amplitude in section view (C) and RMS amplitude co-rendered with depth iso-lines in map view (D). In this picture, the high resistive anomaly confined in the Cretaceous amplitude anomaly (A and B) is evident, and it is also very clear the correspondence between the resistive anomaly and the RMS amplitude anomaly
in the same sedimentary layer (C). Red dots are EM receivers. Seismic and resistivity images courtesy of WesternGeco; CSEM input data courtesy of EMGS.

The amplitude anomaly highlighted by the seismic processing is correspondent to the resistive anomaly found with CSEM modeling and inversion. Different interpretations are possible. The high RMS amplitudes and concurrently resistive anomaly in the Cretaceous sequence indicates that these layers could be charged with hydrocarbons. The fact that the absolute value of the resistivity in the Cretaceous anomaly is so high could be an indication that the hydrocarbon should likely be gas. However, the unclear presence of a structural trap could also indicate that it is only a layer of highly compacted and cemented sediments.

Conclusions

Multi-measurement integration in a portion of the West Loppa area in the Barents Sea allows a more precise definition of geologic features that, considered in each different dataset separately, have a level of uncertainty higher than the one observed when the same features are considered integrating different models coming from different methodologies. This is very important especially in case of frontier exploration, in areas like the Barents Sea where derisking is fundamental in planning wells and infrastructures for the E&P industry.

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References


