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Styles of Shallow Gas Migration and Accumulation on the Norwegian Continental Margin

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SUMMARY

We have acquired P-Cable data from four locations with shallow gas accumulations on the Norwegian continental shelf. Two of the areas are characterized by a high density of pockmarks and pipe structures indicating focused fluid flow throughout the Neogene. The presence of shallow gas accumulations poses both a risk and a chance to the offshore industry. When abundant, such as in the case of the Peon field, the natural gas is a valuable resource. When occurring in small pockets insufficient mapping of the gas can lead to disastrous blow-outs such as the West Vanguard accident. The high-resolution data from the P-Cable system provide us with the possibility to map in detail the occurrence of shallow gas pockets and the accompanying migration structures. This allows better understanding of the underlying fluid and gas migration processes on the Norwegian continental margin.

Introduction

The continental margin of Norway hosts numerous large deep-seated and shallow accumulations of gas. Fluids and gas are constantly migrating from these reservoirs to the sea bed. In some areas vertical pipes and pockmarks provide evidence of past episodes of gas migration while in other areas these structures are still active. Natural marine gas hydrates are present in the Storegga area off mid-Norway, off Svalbard and in the Barents Sea. The gas hydrates occur associated with shallow gas accumulation. Because gas hydrate formation reduces the permeability of the sediments they cause significant overpressures of the gas below. Both the shallow gas and gas hydrates represent potential hazards, and information on their distribution is crucial when designing and constructing sea bed installations or during drilling for deeper hydrocarbons.

Shallow gas and gas hydrates may also have a major impact on climate as large-scale methane release may accelerate global warming. Although at the moment the methane flux rates from sediments to the atmosphere are small compared to other sources of methane, there is strong evidence that there have been episodes in the geological past when large amounts of methane escaped from the sedimentary basins causing global warming. It is likely that small temperature variations that surpass a threshold can have large impact on the global climate.

Accumulations of shallow gas and gas hydrates can also be a potential energy resource. A number of countries such as Japan, India, Taiwan, Korea and Norway are actively researching the possibility to exploit gas hydrates and shallow gas reservoirs. The Peon gas discovery in the northern North Sea may contain commercial shallow gas accumulations. Intriguingly, it may also be possible to store large amounts of CO_2 in methane hydrate areas during the production of natural gas. A wide range of research projects are actively pursuing this scenario. In this context it is important to understand the gas migration mechanisms to be able to predict the consequence when exploiting gas from shallow reservoirs or storing CO_2 in shallow traps.

For an improved understanding of the gas migration processes it is important to map the distribution of free gas and gas hydrates with high spatial and vertical resolution. We have acquired several high-resolution 3D surveys on the Norwegian margins using the P-Cable technology (Figures 1 and 2). The 3D seismic cubes were acquired along the margin from the northern North Sea in the south to the western Svalbard margin in the north, in water depth varying from less than 300 meters to about 1300 meters. The survey areas reveal different styles of gas migration and illustrate the various gas storage and migration processes.

Data and Methods

The P-Cable technology provides an effective way of acquiring high-resolution 3D seismic data. The P-Cable system consists of a seismic cable that is towed perpendicular to a vessels steaming direction (Figure 2). The first P-Cable system, P-Cable1, is a 12 streamer analogue system that was developed by Volcanic Basin Petroleum Research (VBPR) and National Oceanography Center, Southampton (NOCS) in collaboration with University of Tromsø and industry partners. Seven cubes have been acquired using this system. The P-Cable2 was developed in 2006-2007 and is a digital system. The P-Cable2 has been used with up to 24 streamers and seven cubes have been acquired using this system. The P-Cable3 is now developed in collaboration with Geometrics Inc. and will be commercially available in 2011.

The Peon cube was acquired in 2009 outside Florø for Statoil using the P-Cable2 system with 24 streamers onboard the M/V Bjørkhaug operated by Maritim Management. The Nyegga, Vestnesa and the Barents Sea cubes were all acquired using the P-Cable2 system with 16 streamers onboard the University of Tromsø's vessel R/V Jan Mayen. These cubes were acquired in 2007, 2008 and 2009. Data processing comprised navigation processing, tidal corrections, filtering, and post-stack time migration using the RadexPro software. The frequency content is typically 35-250 Hz and the spatial resolution ranges from 6 to 12.5 m.

Results

The Peon field is a large shallow gas reservoir in water depths of about 300 meters (Figure 3). There are no visible signs of gas migration to the sea bed and there are no signs of gas hydrates in the area presumably because the water depth is too shallow for hydrates to be stable at the sub-bottom temperatures.

The Nyegga area is on the northern flank of the Storegga Slide. Water depth ranges from 600 to 1200 meters. The area is characterized by an interlayering of hemi-pelagic and contouritic sediments and a high density of pockmarks and pipe structures that provide evidence for three episodes of gas migration to the sea bed (Figure 4; Plaza-Faverola et al., subm.). However, seepage from pockmarks in this area must be subdued compared to previous seep episodes as no gas flares have been observed in spite of intensive surveying. Nevertheless, sampling of methane hydrates at the seabed shows that there is active gas seepage because hydrates can only be stable at the seabed if there is above average methane advection from the sub-surface. A strong bottom simulating reflector (BSR) throughout the Nyegga area is evidence for the presence of gas hydrates and a significant free gas zone at the base of the hydrate stability field (Bünz et al., 2003).

The two Barents Sea cubes were acquired in 300 meters water depth. The sea bed in this area is rough as it was formed by ice sheet erosion during the Plio-/Pleistocene ice ages. In many parts it is characterized by up to 15 meter deep iceberg plough marks. There is a major regional angular unconformity, URU, separating the glacial sediments from the underlying gently dipping sediments. There are large accumulations of shallow gas and minor gas hydrates in the area. The Barents Sea is characterized by a wide range of gas migration features, and the absence of correlation with the glacial erosion rates suggest that the underlying fluid migration processes have been ongoing far longer than the last glaciations (Vadakkepuliyambatta et al., 2010).

The Vestnesa cube was acquired in 1300 meter deep water west of Svalbard. The closely layered sediments in the area are pierced by numerous vertical pipe structures. These pipe structures terminate as pockmarks on the sea bed. Seismic attribute analysis suggests the presence of a 200 meter thick gas hydrate layer overlying a layer of free gas (Petersen et al., 2010).

Conclusion

We have acquired P-Cable data from four locations with shallow gas accumulations on the Norwegian continental shelf. Two of the areas are characterized by a high density of pockmarks and pipe structures indicating focused fluid flow throughout the Neogene. The presence of shallow gas accumulations poses both a risk and a chance to the offshore industry. When abundant, such as in the case of the Peon field, the natural gas is a valuable resource. When occurring in small pockets insufficient mapping of the gas can lead to disastrous blow-outs such as the West Vanguard accident. The high-resolution data from the P-Cable system provide us with the possibility to map in detail the occurrence of shallow gas pockets and the accompanying migration structures. This allows better understanding of the underlying fluid and gas migration processes on the Norwegian continental margin.

Acknowledgements

The Vestnesa, Barents Sea and Nyegga data were acquired by the University of Tromsø with support from the GANS project. The Barents Sea survey received additional support from Lundin Petroleum. The Peon data were acquired by P-Cable 3D Seismic as and Maritim Management for Statoil. The P-Cable technology is patented (Planke and Berndt, 2003).

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Figure 1: *Location map showing the four study areas.*

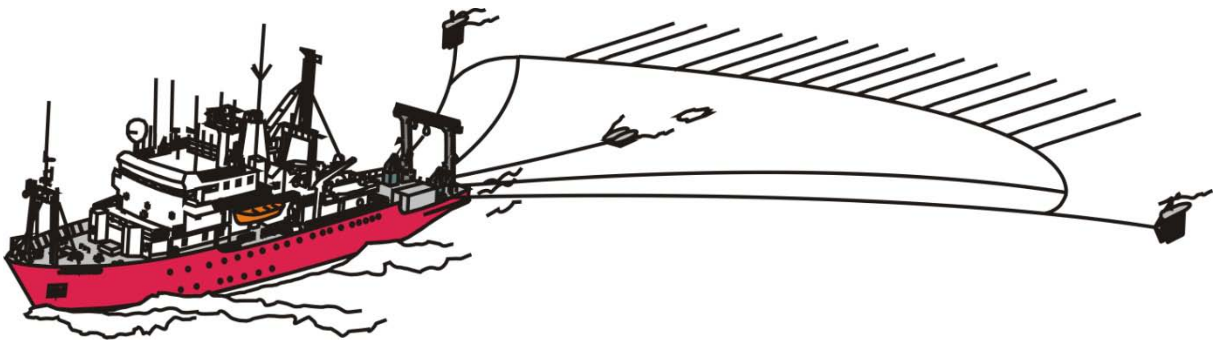

Figure 2: *Sketch of the P-Cable system. A cross cable is extended by two paravanes. A number of short streamers, typically 8 to 24, are attached to the cross-cable (Planke and Berndt, 2003).*

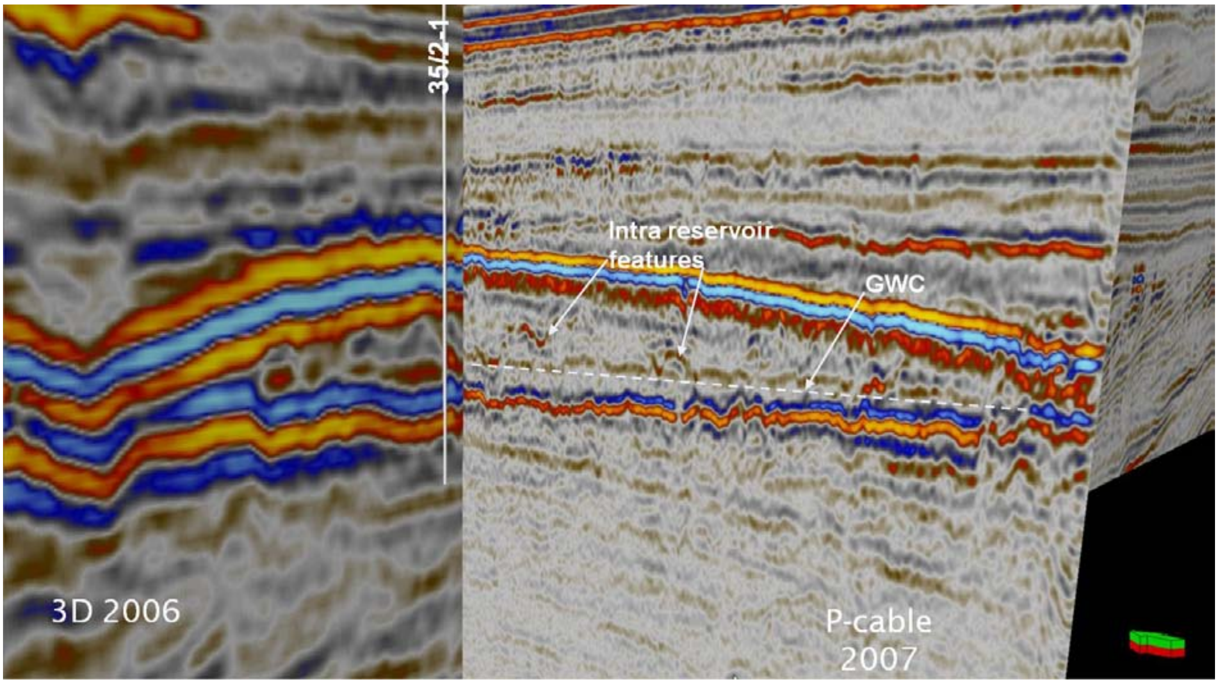

__Figure 3:__ Seismic example of the P-Cable (right) and conventional (left) 3D data of the Peon discovery. Image courtesy of Statoil.

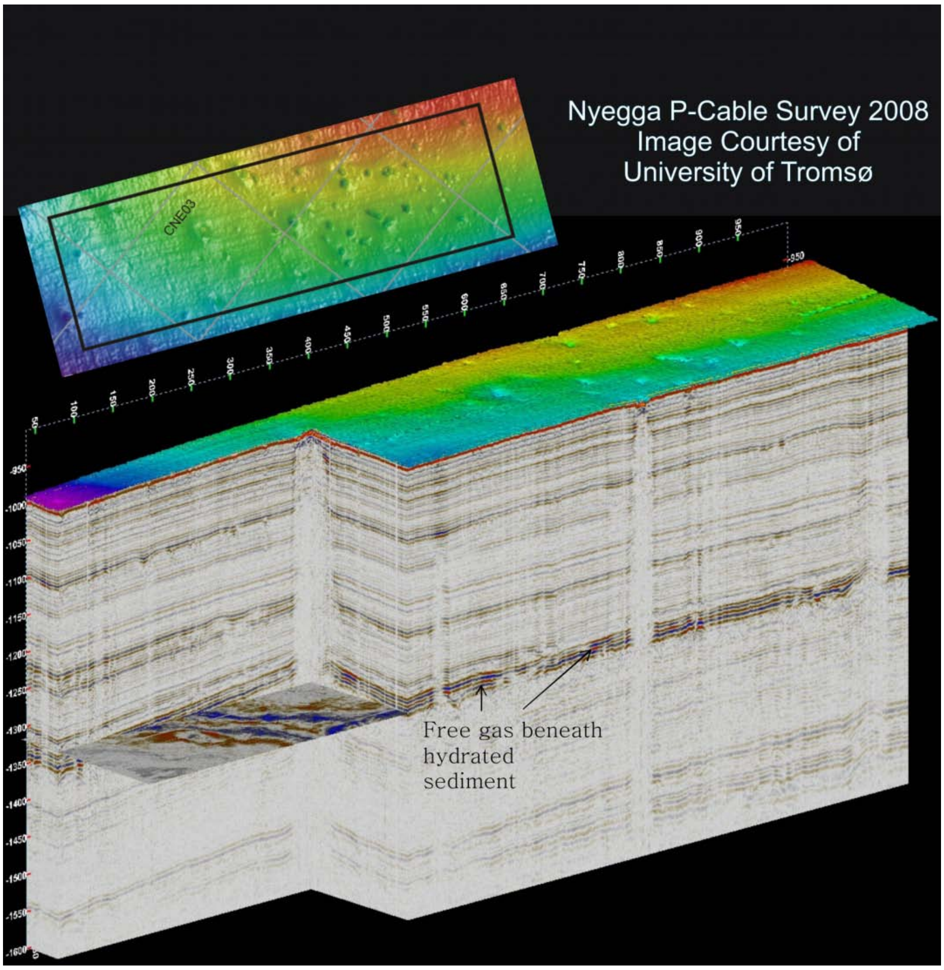

__Figure 4:__ Seismic example of the Nyegga cube showing free gas, pipe structures and pockmarks.