P-Cable High-Resolution 3D Seismic Imaging of Gas Hydrates and Shallow Gas

S. Planke (VBPR), S. Bünz (University of Tromsø), C. Berndt (GEOMAR), O. K. Eriksen (P-Cable 3D Seismic), F.N. Eriksen (P-Cable 3D Seismic) & J.E. Lie (Lundin Petroleum)

Summary

High-resolution 3D seismic data allows detailed mapping of gas hydrates and shallow gas on continental margins and shelves. New P-Cable 3D seismic data suggest the presence of gas hydrates and shallow gas in the epicontinental Barents Sea. A gas mix with higher order hydrocarbon gases are likely required to form hydrates in this region.

Introduction

The ability to image and map gas hydrates in great detail is essential to assess the hydrocarbon reservoir size and potential geohazards. The P-Cable 3D seismic system has been developed over the past decade to image the shallow geology with high vertical (50-300 Hz) and horizontal (3-6 m in-line spacing) resolution. Gas hydrates and shallow gas have been a primary target for many of the almost 50 cubes acquired so far, e.g. on the Hydrate Ridge, in the Gulf of Cadiz, and offshore mid-Norway (e.g., Hornbach et al., 2012). In addition, six cubes acquired in the Barents Sea have focused on gas hydrate and shallow gas targets (e.g., Petersen et al., 2010), including one 4D study area.

Data and Methods

A 7x2.5 km large cube was acquired in 300 m water depth on Tromsøflaket in 2009 using the University of Tromsø vessel R/V Jan Mayen. A total of 59 lines were collected in a five day period with a 8 to 12 streamer P-Cable2 system. Navigation and 3D seismic processing was done by Deco Geophysical using the RadexPro P-Cable module and interpreted using the KingdomSuite software.

Results

The sea floor in the area is very rough with deep iceberg plough marks (Figure 1a). An approximately 100 m thick sequence of glacial deposits is separated from westward-dipping Paleogene sequences by a regional unconformity, URU. The rough sea floor does not strongly influence the imaging of the intra-glacial and deeper boundaries. Locally, high-amplitude reflections are identified at intra-glacial and URU levels. These events are interpreted as shallow gas. A negative polarity, high-amplitude cross-cutting reflection, TG, is present 0.75-0.8 s. An RMS amplitude extraction along this reflection reveals a hummocky geometry, and local areas where TG is absent (Figure 1b). We interpret this reflection to represent free gas trapped beneath a low-permeability gas hydrate layer. However, free gas is sometimes also trapped within the gas hydrate stability zone (GHSZ). Modeling by Chand et al. (2008) shows that the Barents Sea is outside the GHSZ zone for pure methane hydrates (Figure 1c). However, a mixture of methane and minor higher order hydrocarbons are in the GHSZ to several hundred meters below the sea floor (Figure 1d). A variable geothermal gradient and the saltiness of the formation water can explain a variable thickness of the GHSZ (Chand et al., 2008).

Conclusions

High-resolution 3D data has major potential to image gas hydrates and shallow gas in a cost-efficient way. Five academic and commercial P-Cable systems are presently available.

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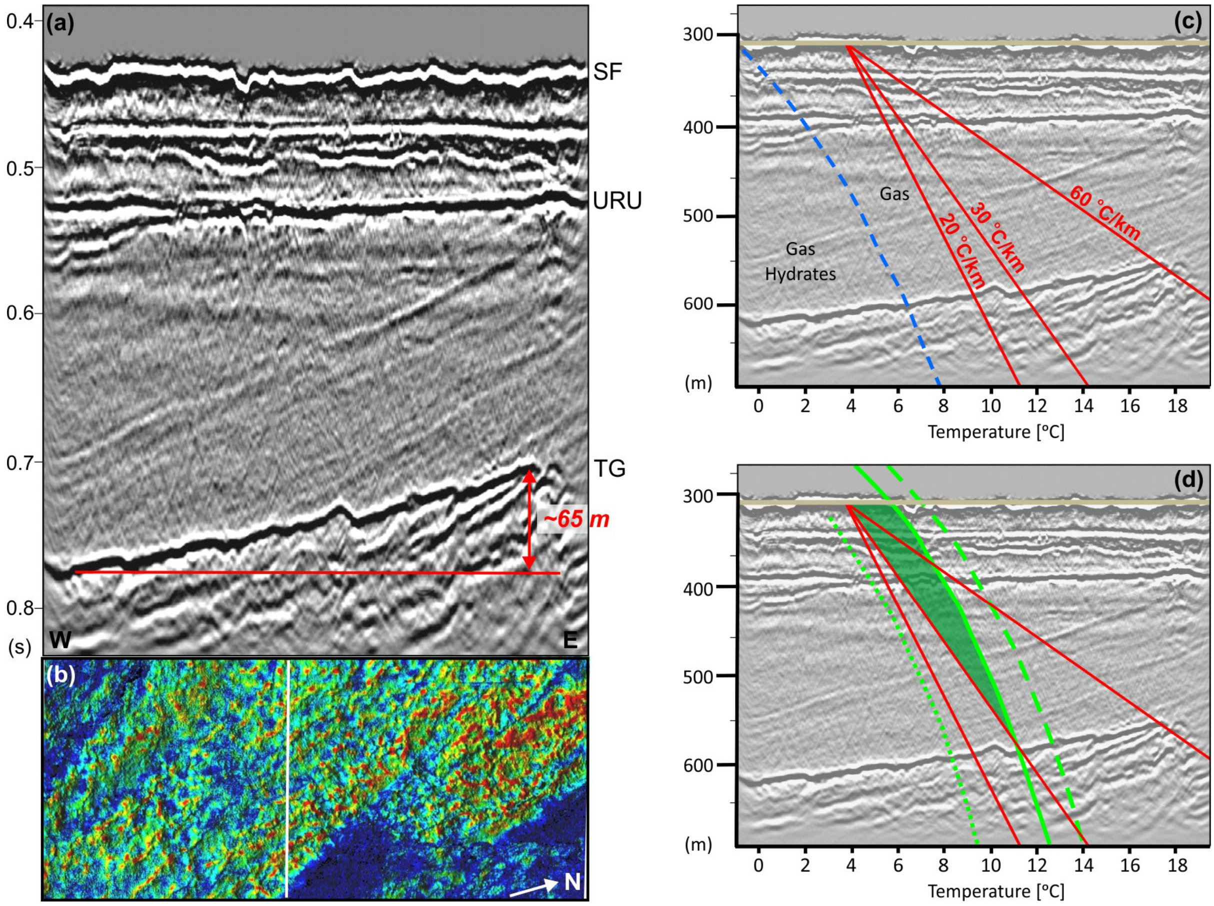

Figure 1 *Seismic evidence of gas and gas hydrates in the SW Barents Sea. (a) Cross-line showing the seafloor (SF), the Upper Regional Unconformity (URU), and the high-amplitude, negative polarity Top Gas (TG) reflections. TG is cross-cutting westward-dipping Paleogene sedimentary reflections terminating at URU. The dip of TG is approximately 1.7 degrees, and the width of the cube is 2680 m. (b) RMS amplitude map of TG showing an "orange-peel" texture. Gas is interpreted in areas with high amplitudes (red and green). (c) Gas hydrate - free gas phase boundary (blue line) of methane hydrate in the SW Barents Sea and temperature gradients (red lines) modified from Chand et al. (2008). The figure shows that no methane hydrates are expected for a wide range of temperature gradients (20-60^{o}C/km) in the study area. The graph is plotted on top of the seismic profile in (a). (d) Gas hydrate-free gas phase boundary (green solid line) of a gas mixture (96% methane, 3% ethane, 1% propane) based on Chand et al. (2008). The model shows that gas hydrates are present from the sea floor down to about 600 m depth for a realistic temperature gradient of 30 ^{o}C/km (green transparent polygon). Increasing pore fluid salinity would lead to a large gas hydrate stability field (dashed line) whereas fresh water pore fluids lead to a smaller stability field (dotted line).*

References

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