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## P-cable High Resolution Seismic Imaging of Shallow Gas in the Barents Sea

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### SUMMARY

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Two high resolution P-Cable 3D seismic cubes have been acquired in the Barents Sea in 2007 and 2009 to image shallow gas and fluid escape structures. The cubes show that the technology is able to provide images of very high quality above the seabed multiple, comparable or even better than high resolution 2D but with the added benefit of 3D structural control. The new data are useful to map shallow geohazards and petroleum accumulations, and to understand the processes and implications of massive leakage of sediment-bound greenhouse gases.

## Introduction

The Barents Sea contains very large accumulations of shallow gas and associated gas hydrates. The gas is imaged as high-amplitude reflections on seismic reflection profiles. Vertical pipe structures and pockmarks provide evidence of episodes of gas migration to the sea bed. Active sea bed gas seepage has further been documented by ROV video observations and sampling, e.g., on the Håkon Mosby Mud Volcano on the western Barents Sea margin.

Melting of gas hydrates and leakage of gas through the sea bed may contribute to the on-going global warming. Methane is a powerful greenhouse gas (more than 20 times as efficient as CO<sub>2</sub> to trap heat in the atmosphere). Recent findings suggest that degassing of methane due to global warming has already started, and accelerated gas release may have a major impact on future climate.

Shallow gas accumulations are also important for the petroleum industry. Shallow gas represents a drilling hazard. It is therefore important to know the distribution of gas prior to drilling. In recent years the gas accumulations in the Barents Sea have furthermore been seen as potential reservoirs beneath highly compacted glacial sediments. The hydrocarbon industry considers some of these accumulations to have economic significance. Shallow gas is also important in terms of providing windows to deep hydrocarbon reservoirs, and the location of shallow gas might be linked to reservoirs in the less-explored Triassic and Palaeozoic successions.

Detailed mapping of shallow gas accumulations is important to understand gas leakage processes, geohazard implications and the petroleum potential. We have acquired several high-resolution 3D seismic surveys in the Barents Sea to address these questions using the P-Cable technology. The main purpose of these surveys was to determine fluid pathways and sites of gas hydrate formation. In addition, several shallow gas reservoirs have been mapped.

## Data and Methods

The P-Cable system consists of a seismic cable towed perpendicular to a vessel's steaming direction (Figure 1; Planke and Berndt, 2002). A 12-streamer analogue system, the P-Cable1, was developed by VBPR and the National Oceanography Center, Southampton (NOCS) in collaboration with the University of Tromsø and industry partners. The P-Cable1 has been used to acquire seven small cubes offshore Svalbard, in the Barents Sea, in the Gulf of Cadiz, the Mediterranean, and off Oregon (Figure 2). A digital system, the P-Cable2, was subsequently developed in 2006-2007. The P-Cable2 has been used to acquire seven 3D cubes offshore Norway, the largest being ca. 250 km<sup>2</sup> which was acquired using 24 streamers.

The Vestnesa and southern Barents Sea 3D cubes were acquired in 2007 and 2009, respectively, using the University of Tromsø vessel R/V Jan Mayen and the P-Cable2 system with 8 to 12 streamers. Processing included P-Cable geometry, tidal corrections, binning, stacking, migration, frequency filtering, and gain corrections. The final bin size is 6 to 12 m. With a horizontal resolution of 5 m and a maximum vertical resolution of 1-2 m the resolution of the P-Cable data is twice as high as the best industry data acquired with long streamers, and 5 to 10 times better than standard exploration 3D seismic data. This is achieved through innovative processing schemes and because the short streamers can be towed much closer together than long streamers without entangling.

## Results

The Vestnesa cube was acquired in 1300 m deep water, and images a layered sedimentary succession on the western Svalbard margin (Figure 3). The sediments are pierced by numerous pipe structures terminating as pockmarks at the sea bed. Seismic attribute analysis suggests the presence of a ca. 200 m thick hydrate-bearing sedimentary layer overlying high-amplitude reflections representing layers with free gas accumulations (Petersen et al., 2008; Figure 3).

The southern Barents Sea cube was acquired on the shelf in 300 m deep water (Figure 4). The sea bed is very rough and characterized by up to 15 m deep iceberg plough marks. A major regional angular unconformity, URU, separates the ca. 80 m thick Plio-Pleistocene glacial deposits from gently westward-dipping Paleogene sediments.

Internal reflections in the glacial package are sub-horizontal and discontinuous. In contrast, URU is a continuous single-cycle high-amplitude reflection. The Paleogene sequence is characterized by weak westward dipping reflections. However, numerous high-amplitude discontinuous events are present in this succession. The high-amplitude events locally follow the stratigraphic layering just below URU. However, at greater depths (ca. 50 to 100 m below URU) the discontinuous high-amplitude reflections cross-cut the sedimentary layering. We interpret the high-amplitude reflections to represent shallow gas possibly trapped below gas hydrates. Reflection strength data are used to delineate the gas bodies. Six distinct accumulations have been mapped, each sub-divided into separate domains.

### Conclusions

P-Cable data from the Barents Sea shows that the technology is able to provide high-resolution images of shallow gas and fluid migration structures. The imaging from the shallow reservoirs are of very high quality, comparable or even better than high-resolution 2D seismic data but with the added benefit of 3D structural control. The data are useful to map shallow geohazards and petroleum accumulations, and to understand the processes and implications of massive leakage of sediment-bound greenhouse gases.

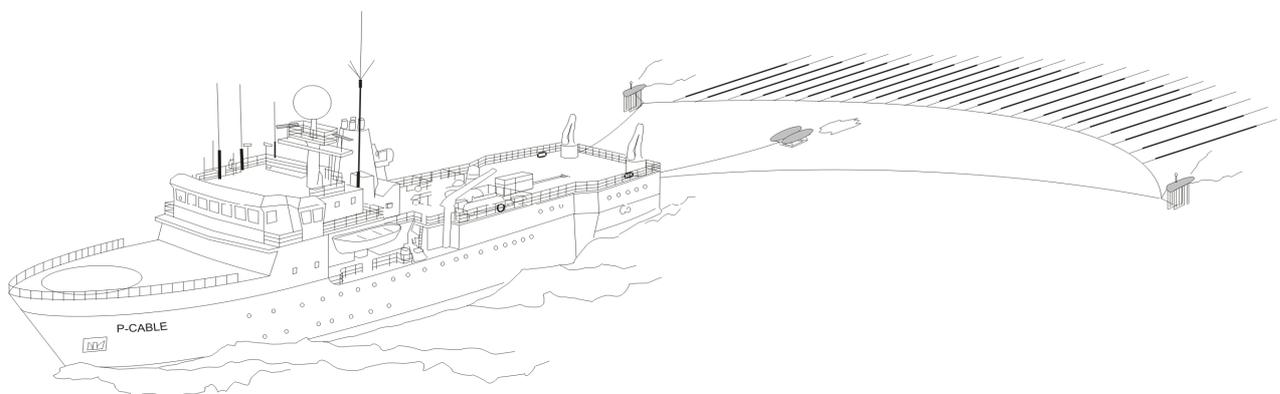
### Acknowledgements

The data were acquired by the University of Tromsø and funded through the NFR Fluid Flow and GANS projects with additional support from Lundin Oil and P-Cable 3D Seismic.

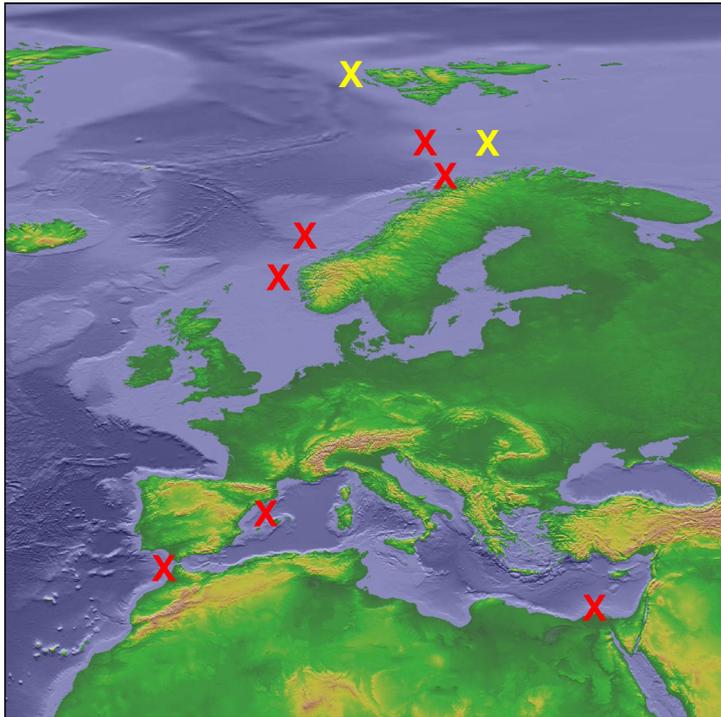
### References

Planke, S. and Berndt, C., 2002. Anordning for seismikkmåling, Norwegian Patent no. 317652 (UK Pat. No. GB 2401684; US Pat No. US7,221,620 B2).

Petersen, C. J., S. Buenz, S. Hustoft and J. Mienert, 2008. 3D seismic imaging of marine gas hydrates in Arctic sediments of the Vestnesa Ridge off the W-Svalbard margin, Proc. 6th International Conference on Gas Hydrates, Vancouver 2008.



**Figure 1:** Schematic diagram of the P-Cable 3D seismic system (Planke and Berndt, 2002). A cross-cable is towed perpendicular to the vessel's steaming direction using two paravanes. Up to 24 short seismic streamers are attached to this perpendicular wire.

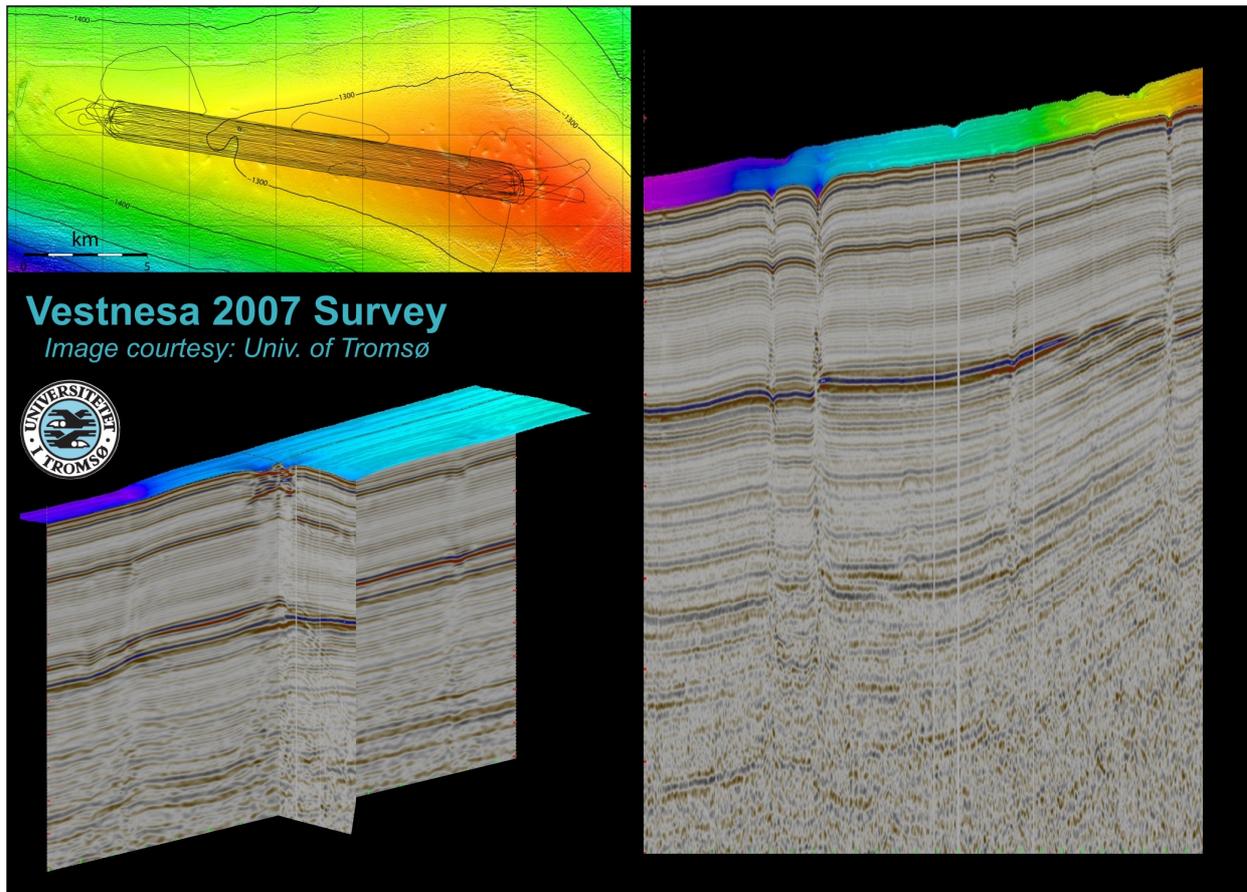


### Main P-Cable Surveys

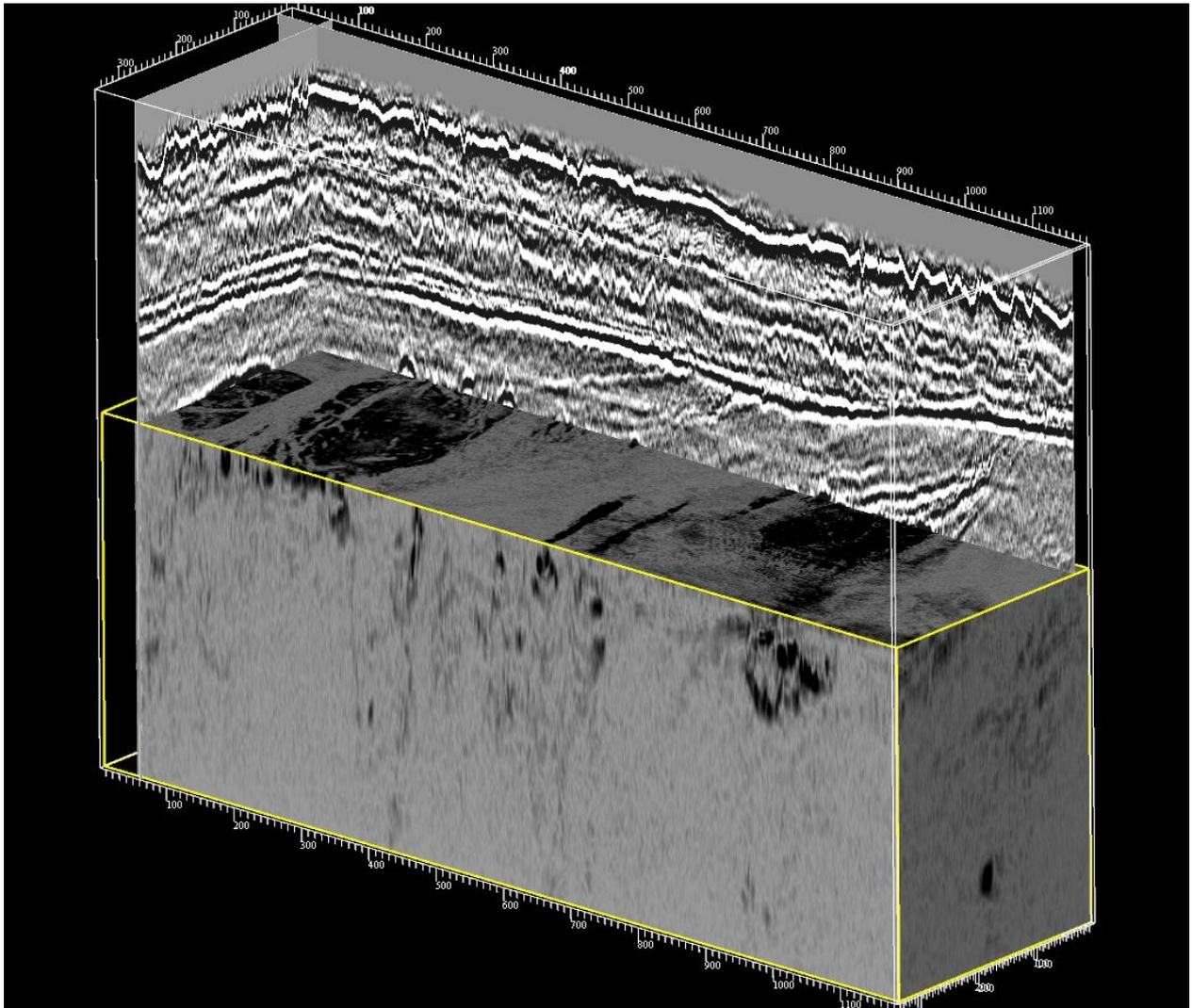
- Svalbard (2004; P-Cable1)
- W Barents Sea (2005; P-Cable1)
- Gulf of Cadiz (2006; P-Cable1)
- North Sea (2007; P-Cable2)
- Vestnesa (2007; P-Cable2)
- Nyegga (2008; P-Cable2)
- North Sea (2009; P-Cable2)
- Barents Sea (2009; P-Cable2)
- Nile Delta (2009; P-Cable 2)

**Total:** 14 cubes (5 to 250 km<sup>2</sup>)

**Figure 2:** Location of P-Cable 3D cubes acquired from 2004 to 2009 (crosses). The Vestnesa and the southern Barents Sea cubes shown in Figures 3 and 4 are marked in yellow.



**Figure 3:** P-Cable data from Vestnesa, a bathymetric ridge west of Svalbard. Upper-left: Ship-track data overlaid on multibeam bathymetry. Lower-left and right: 3D seismic data examples.



*Figure 4: P-Cable seismic data from the southern Barents Sea combining amplitude and reflection strength data. See text for description.*