Integrated Geohazard Solutions

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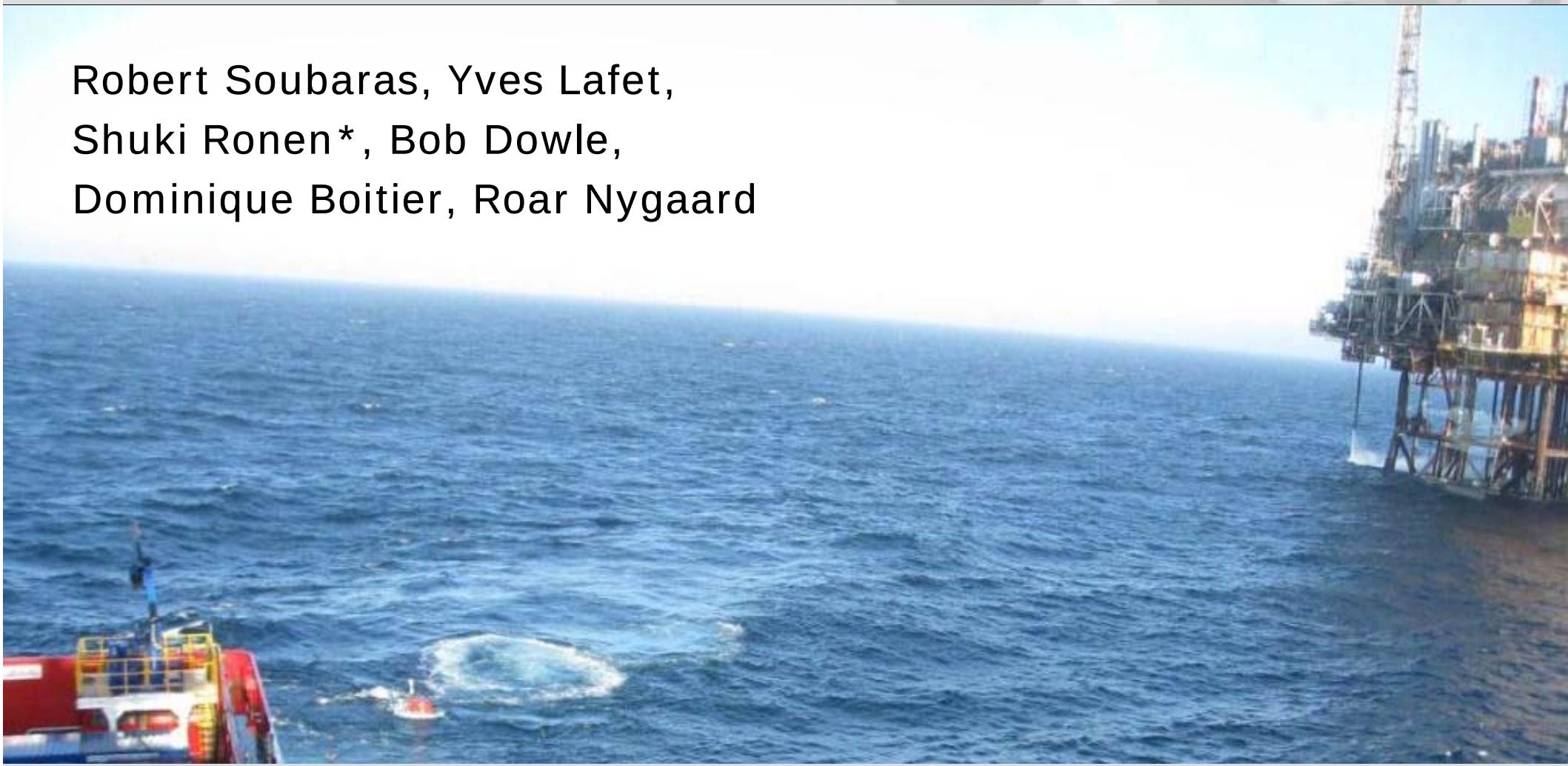
Shuki Ronen*, Bob Dowle,
Dominique Boitier, Roar Nygaard



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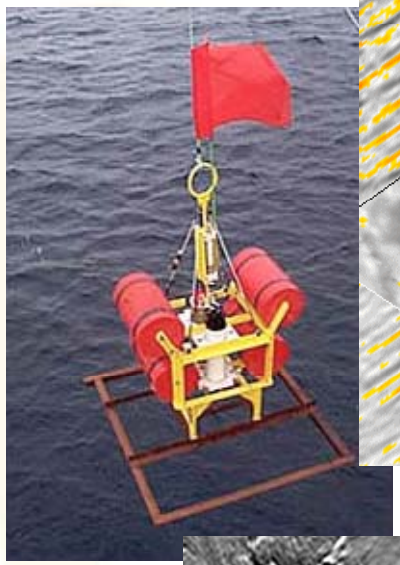
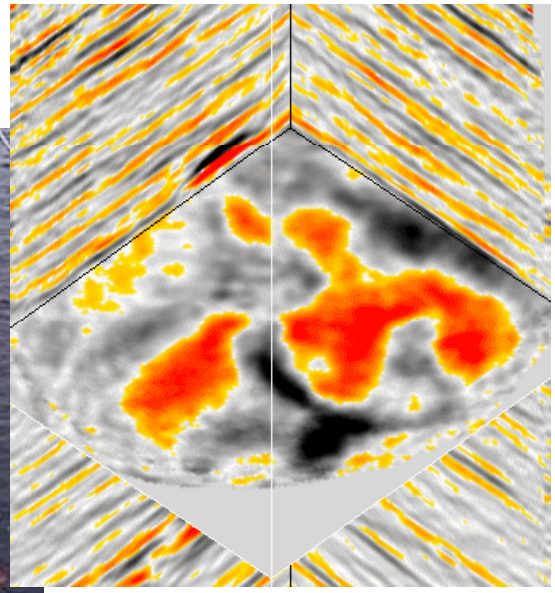
Content

Geophysical methods

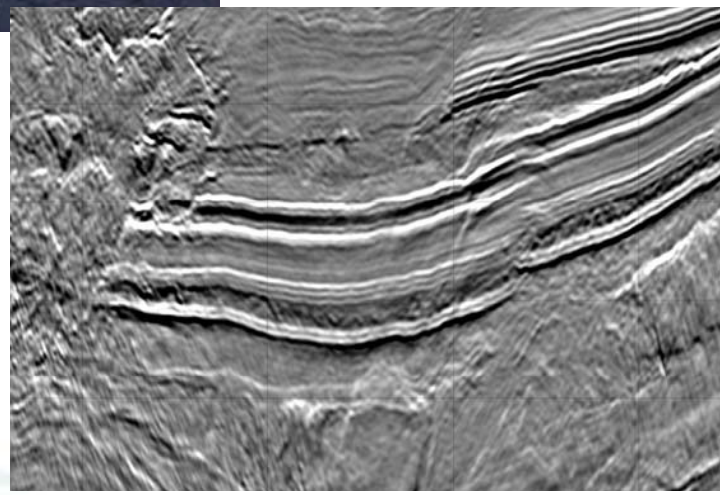
- Surface Towed Streamers
  - They can be broad band
- Ocean bottom nodes
  - P waves
  - Converted PS waves





Geohazard applications

- Shallow Gas
- Gas Hydrates and seabed slides
- Subsidence
- Overpressure
- ...



Warning: this talk is a mile wide and a foot deep

(but in metric units)

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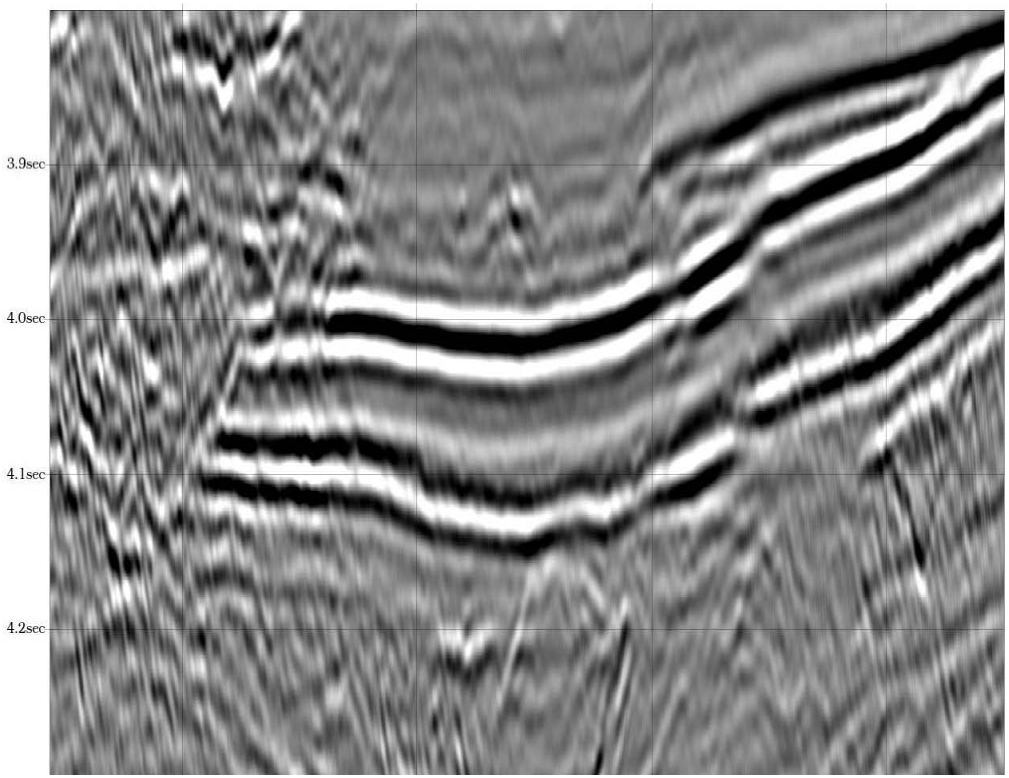
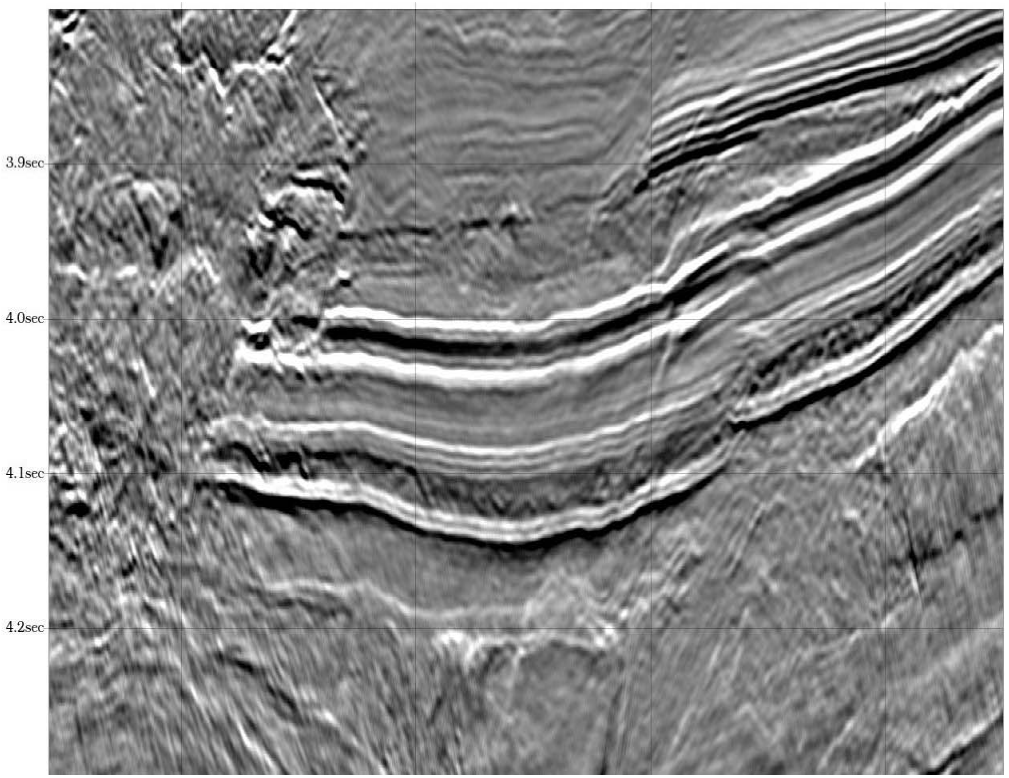
Broadband Seismic

- Variable depth streamer
- Solid streamers
- Multi-level source
- Processing: up+mirror imaging and joint deconvolution



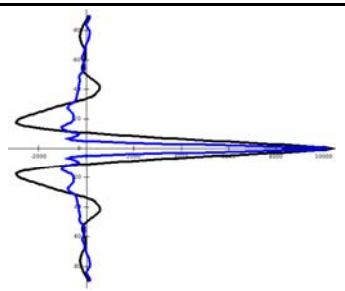
Conventional: 3 Octaves



BroadSeis: 6 Octaves

Extracted wavelets

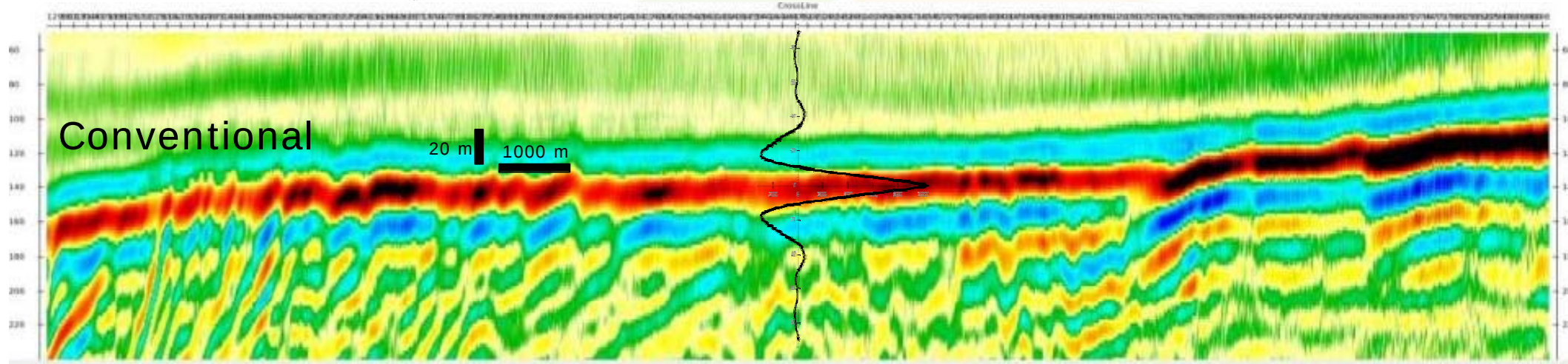
BroadSeis
Conventional

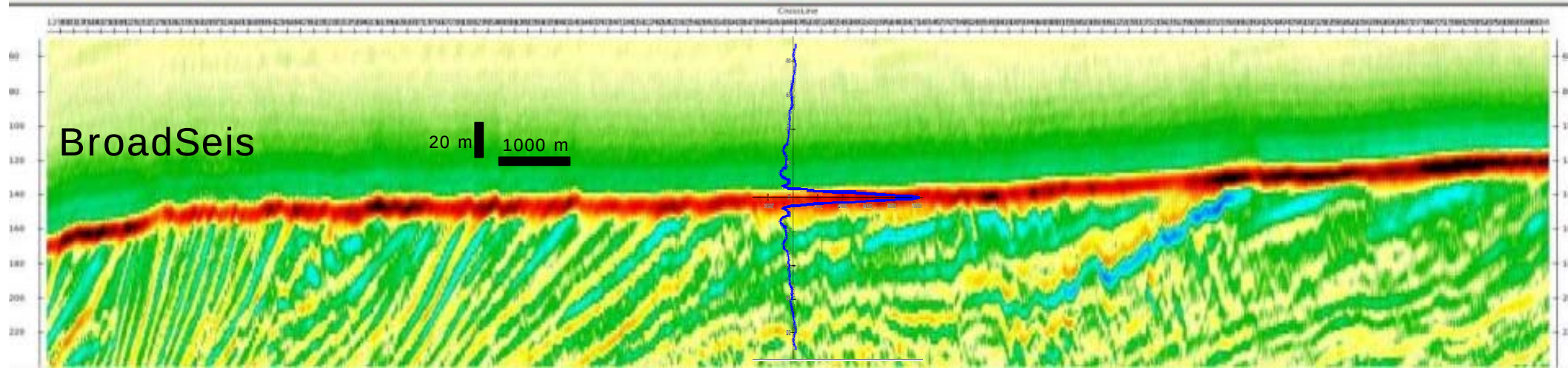


The BroadSeis wavelet has

Better Low frequency ➔low amplitude sidelobes

Better High frequency ➔sharper main lobe





Courtesy of Total, the Republic of Gabon and Cobalt

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3D Broadband time slices—channels

Legacy 3D

BroadSeis

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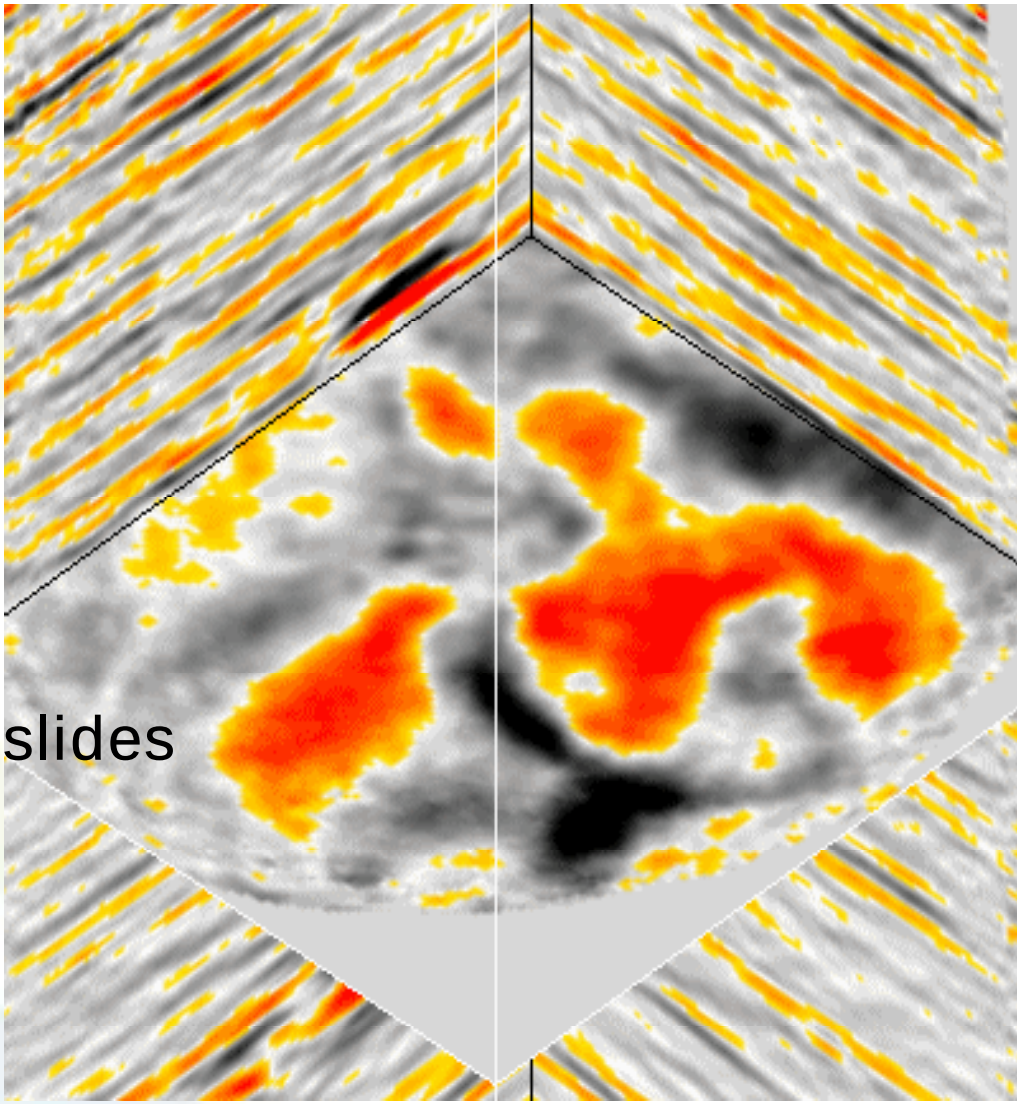

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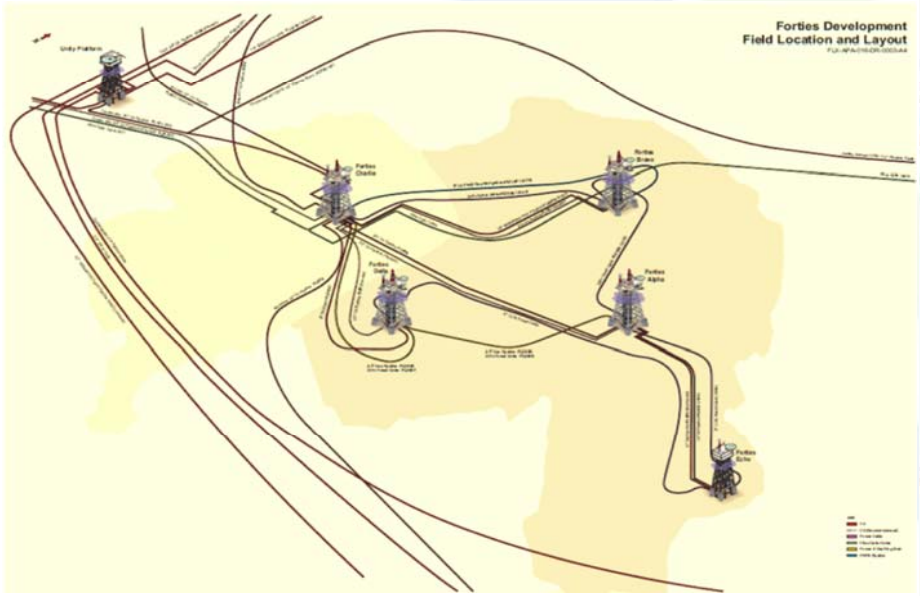
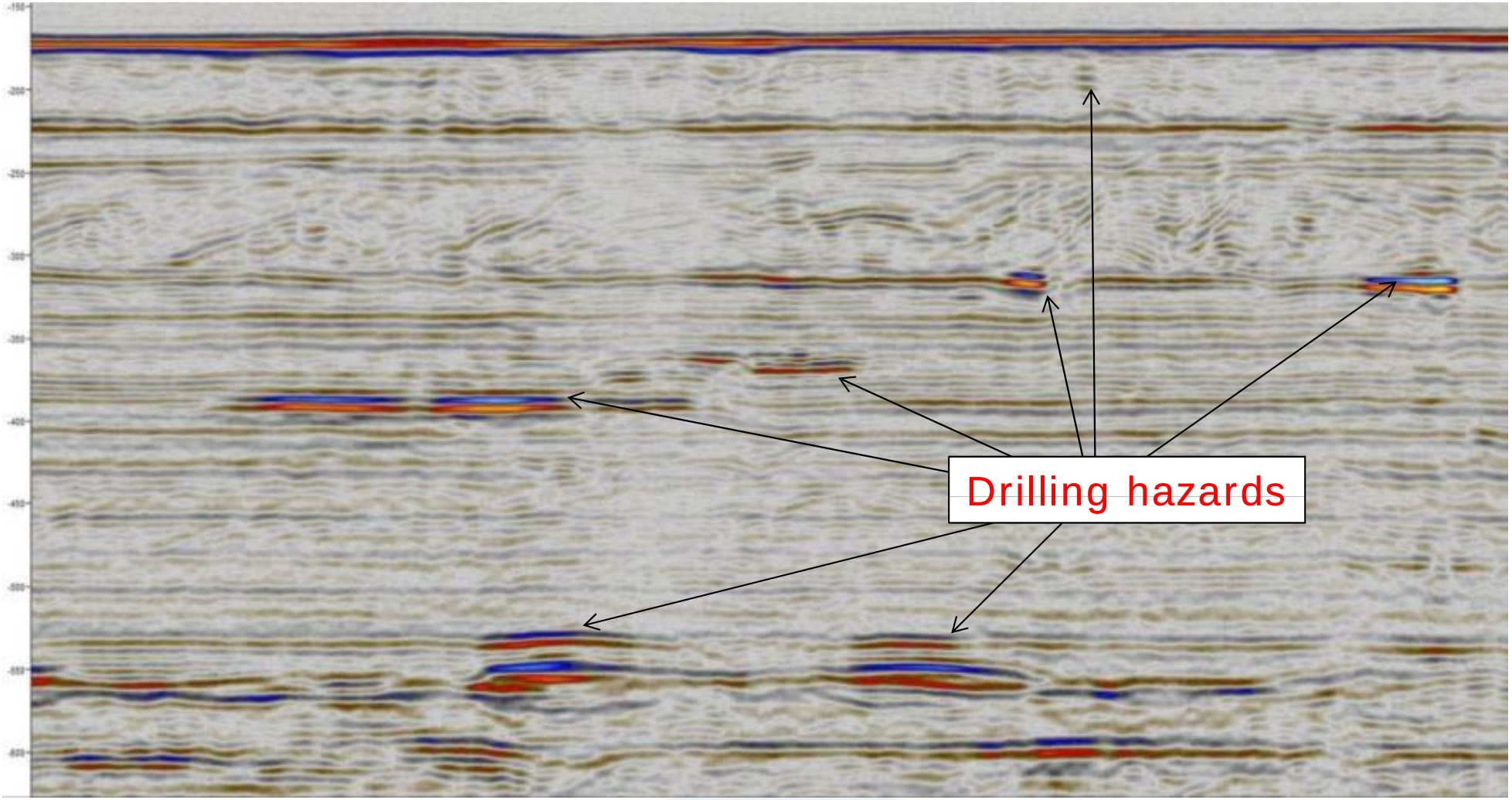
Forties Field

- 2.6 Billion barrels produced since 1975
- Avg 73K barrels / day in 2009 (30K in 2003)
- 5 billion barrels remaining
- 4D program
- Drilling hazards
  - ➢ Shallow Gas

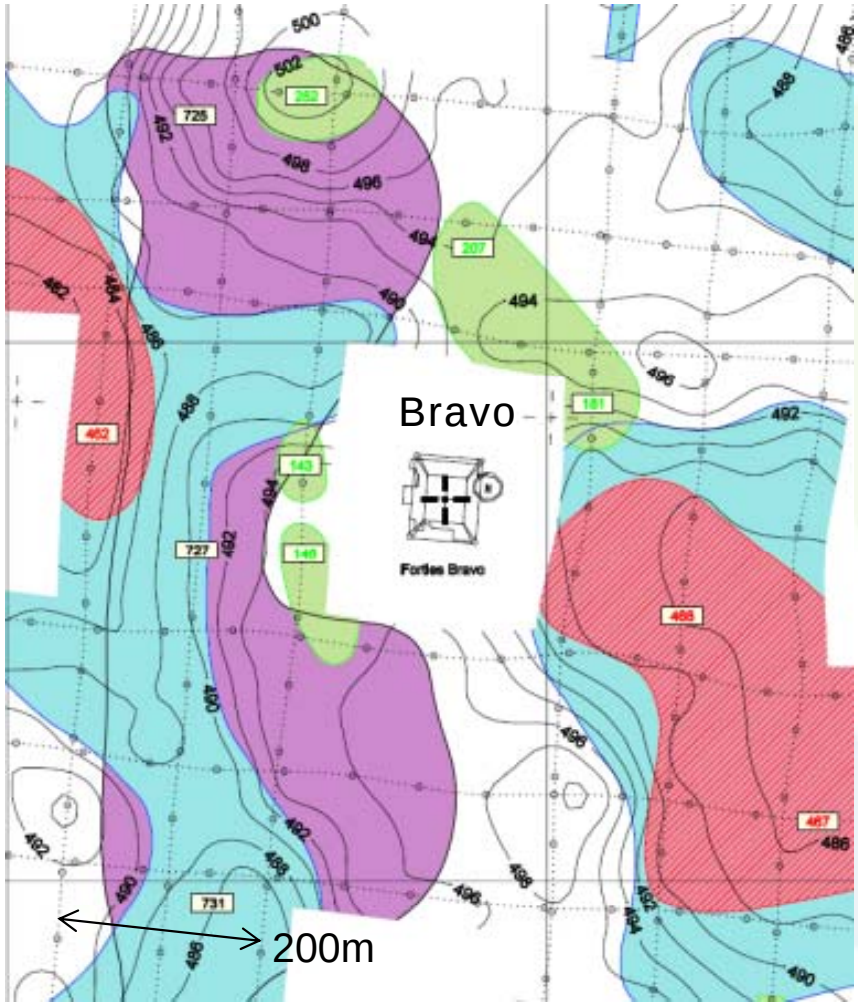


2D mini-streamer site survey



Risky zone is upper 500m within a radius of 100m from the platforms

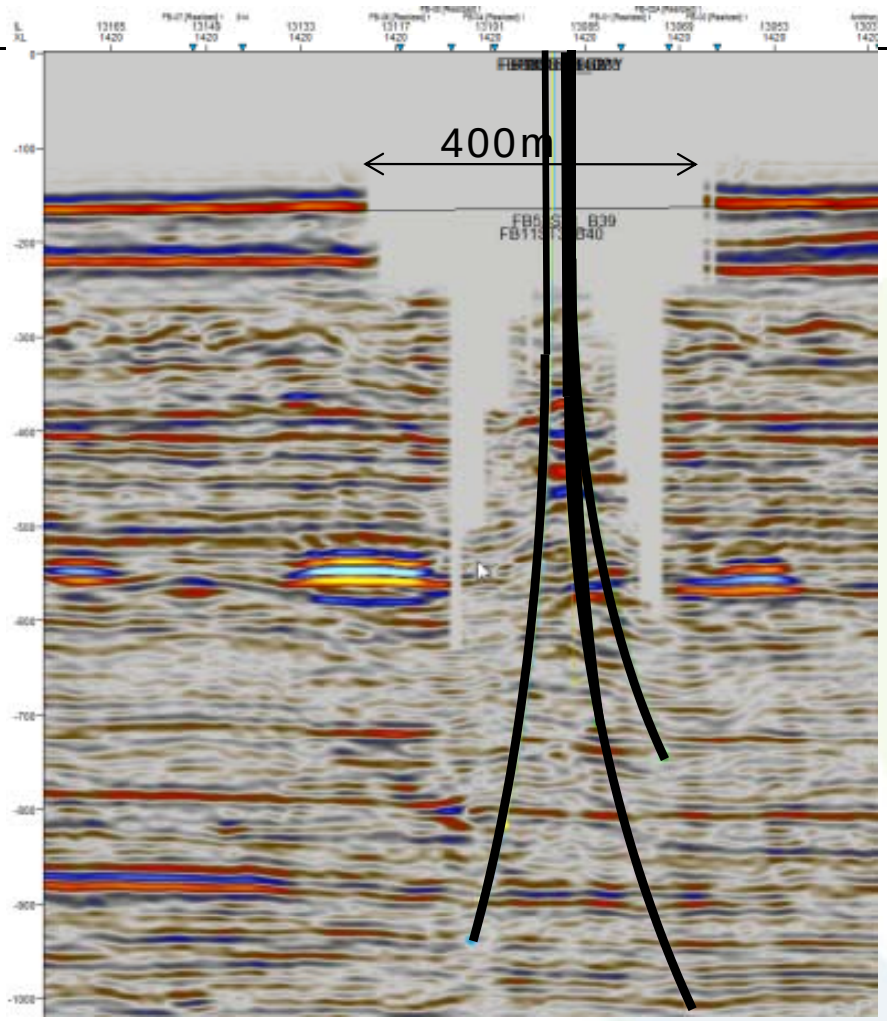
No image under the platforms from 2D streamers



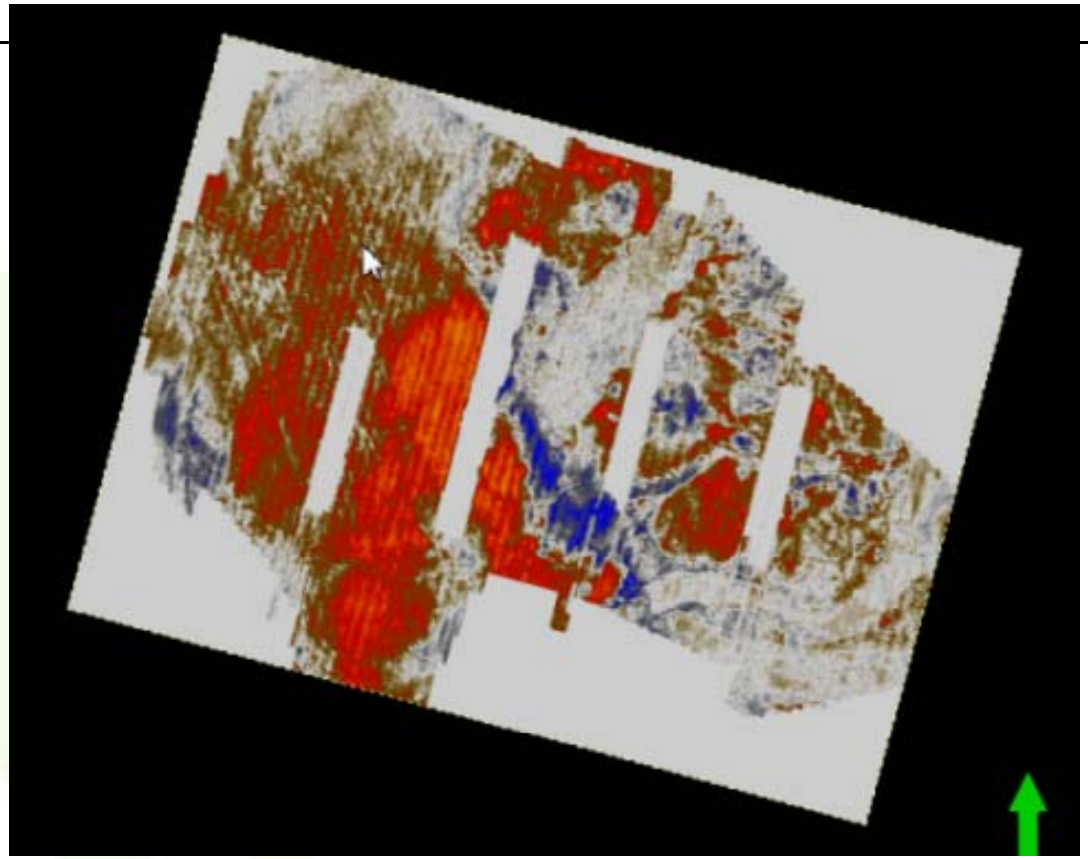
- **2D shallow hazard site surveys around platforms acquired on a 100x100m grid, but have 300x300m hole around platform**
- **Risky zone is from seabed (100m) to Basin Sands (500m) within a radius of 100m from the platform - inside the no-data zone**
- **Significant amount of drilling planned in 2nd half of 2010 and 2011**
- **Increase safety of operations while potentially saving £1 million per well if gas diverter not rigged when not required**

3D streamers undershoot

No image underneath platforms from undershoot



- Risky zone is from seabed (100m) to Basin Sands (500m) within a radius of 100m from platform inside the no-data zone



- 2010 (and 2000 vintage) 3D data provides excellent image of the hazards everywhere, except above 700m in 400m strip around platforms
- Problem requires a new approach to seismic data acquisition.

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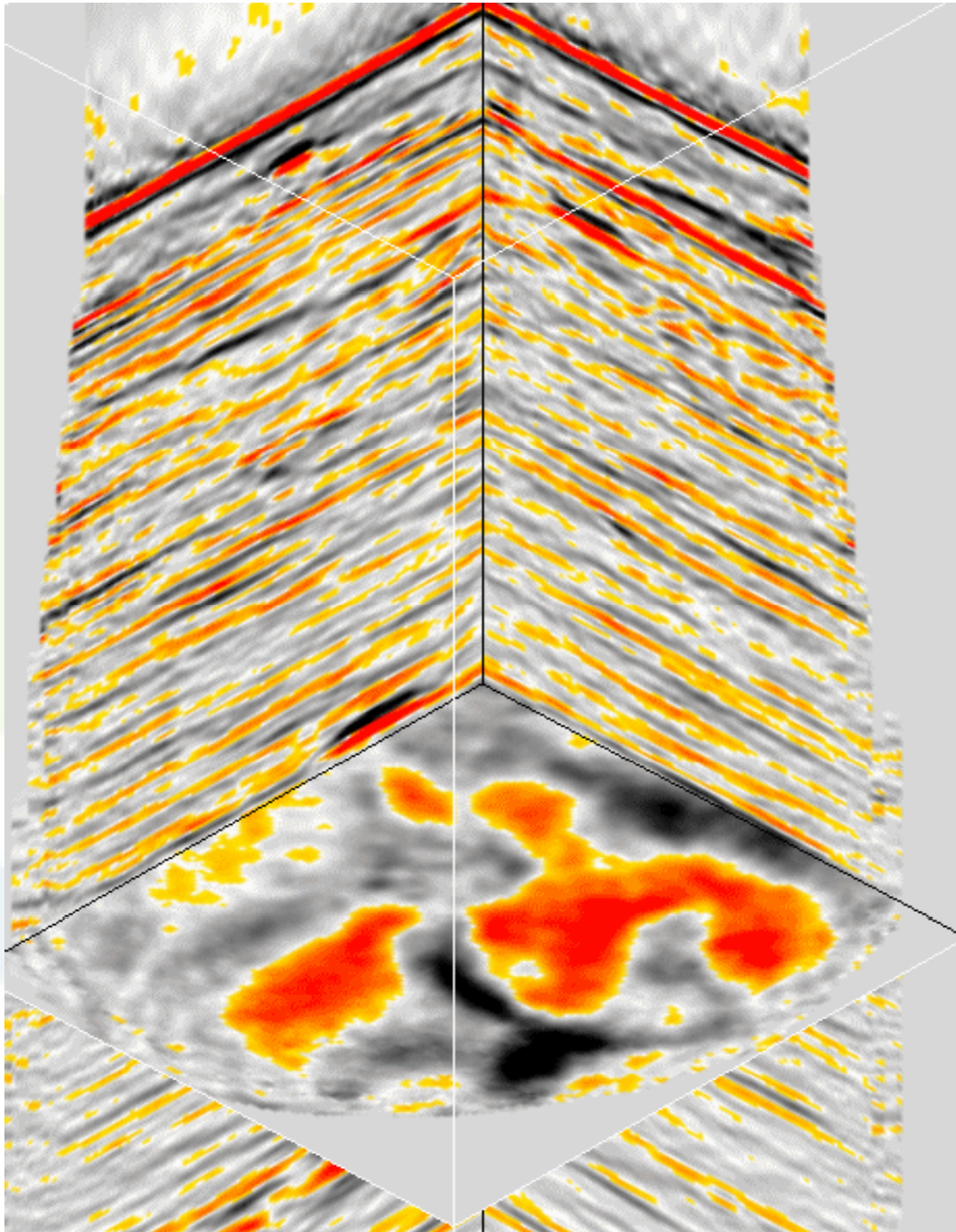
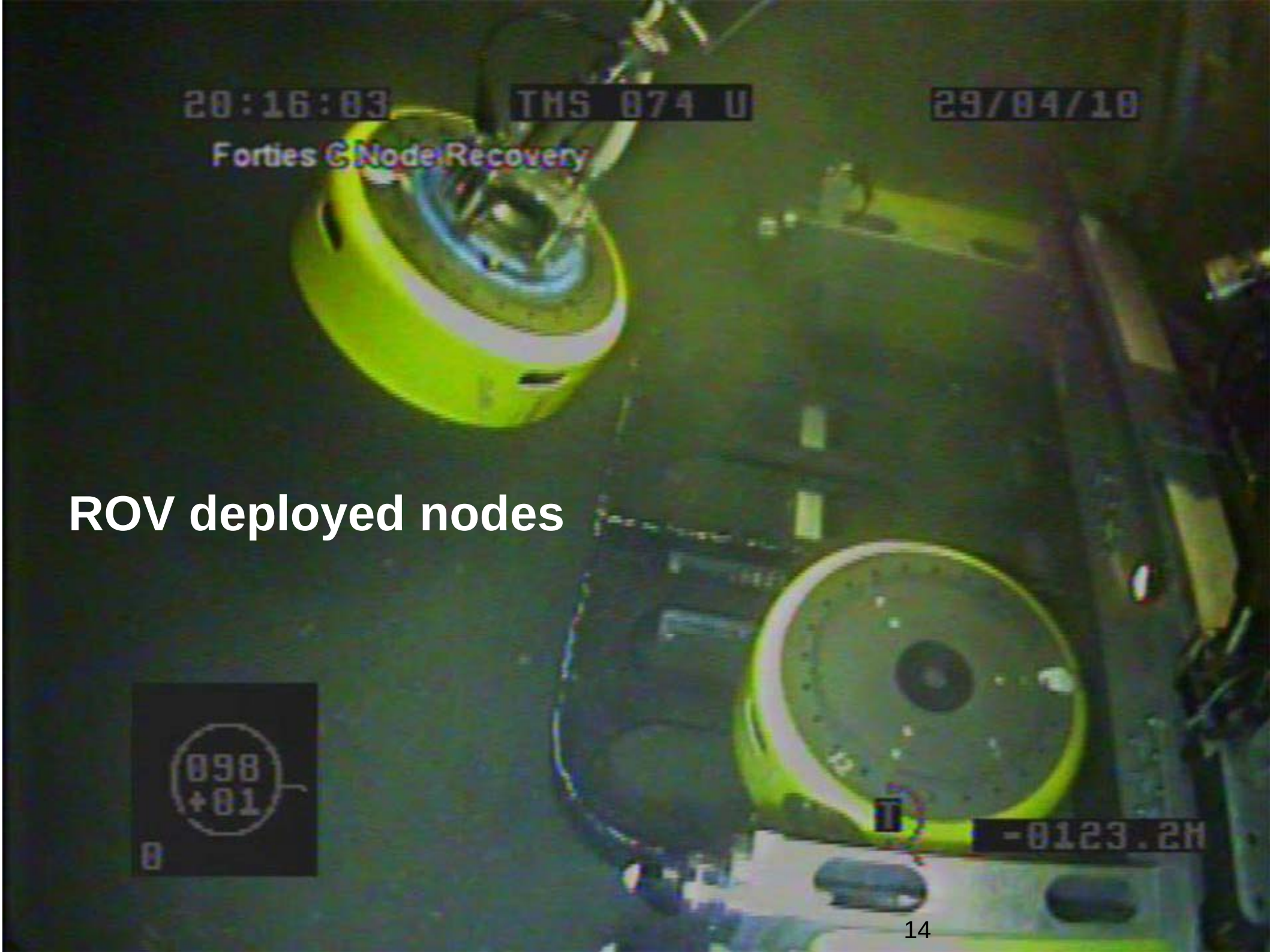
Node survey in the Forties filed



Nov 2, 2010

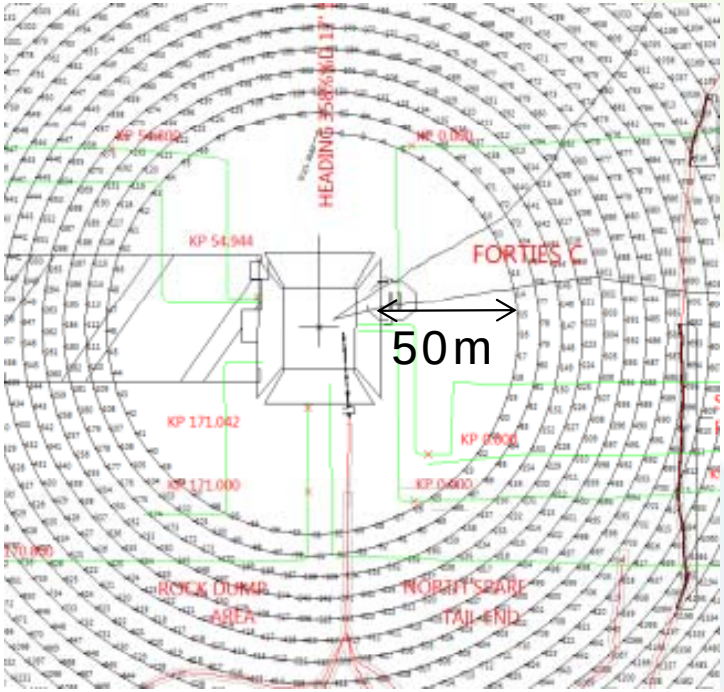


ROV deployed nodes

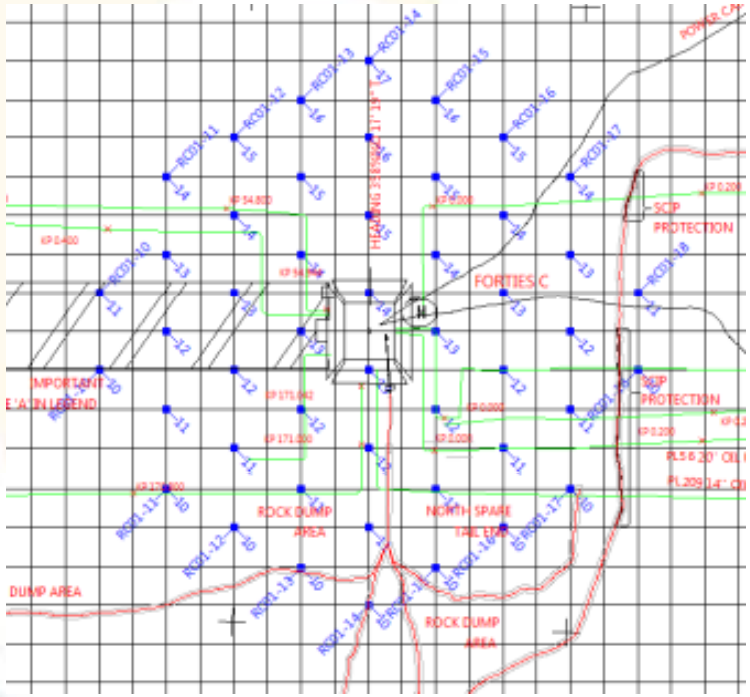
Shooting

Preplot geometry

Spiral source

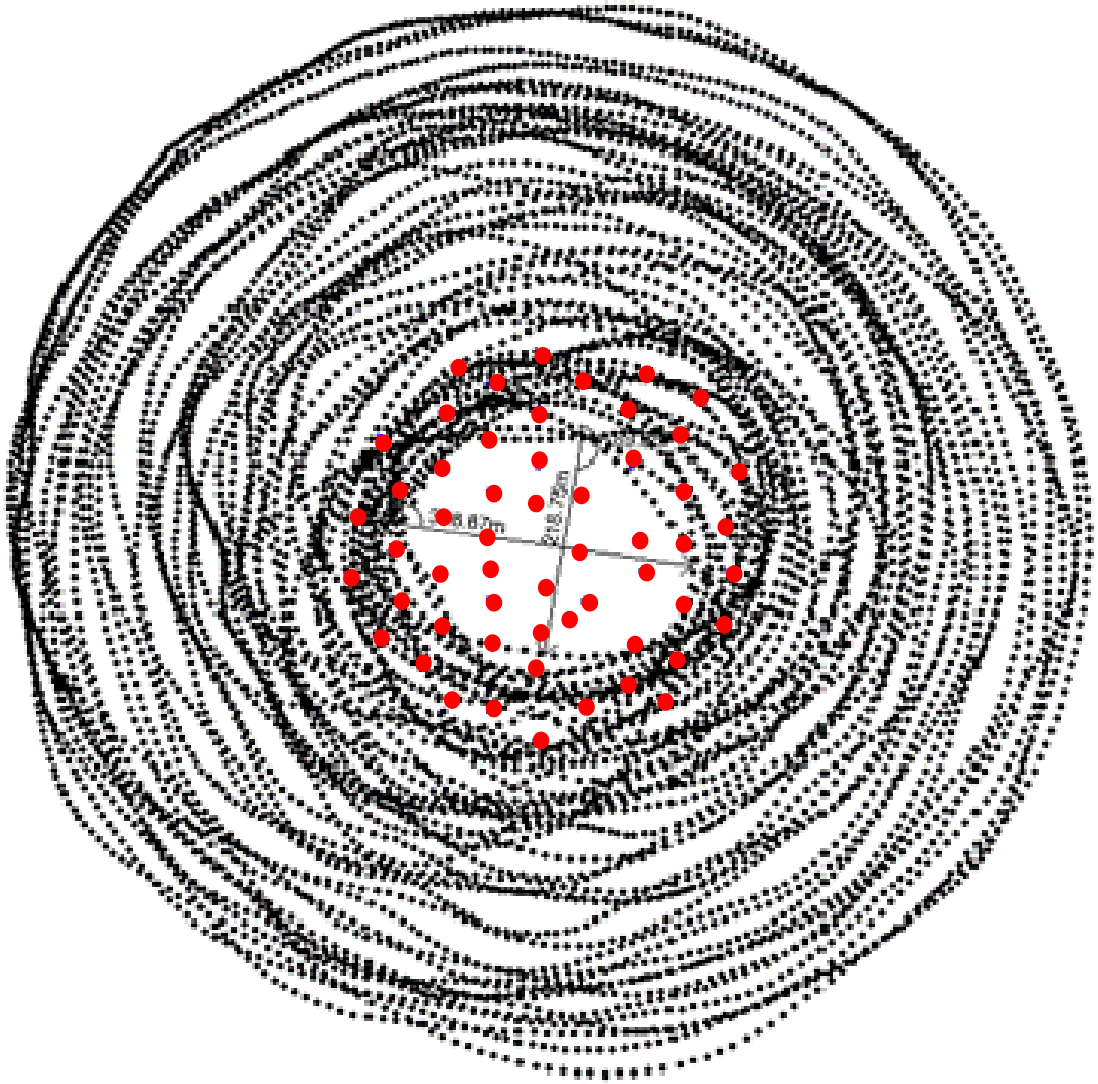


Hexagonal receivers

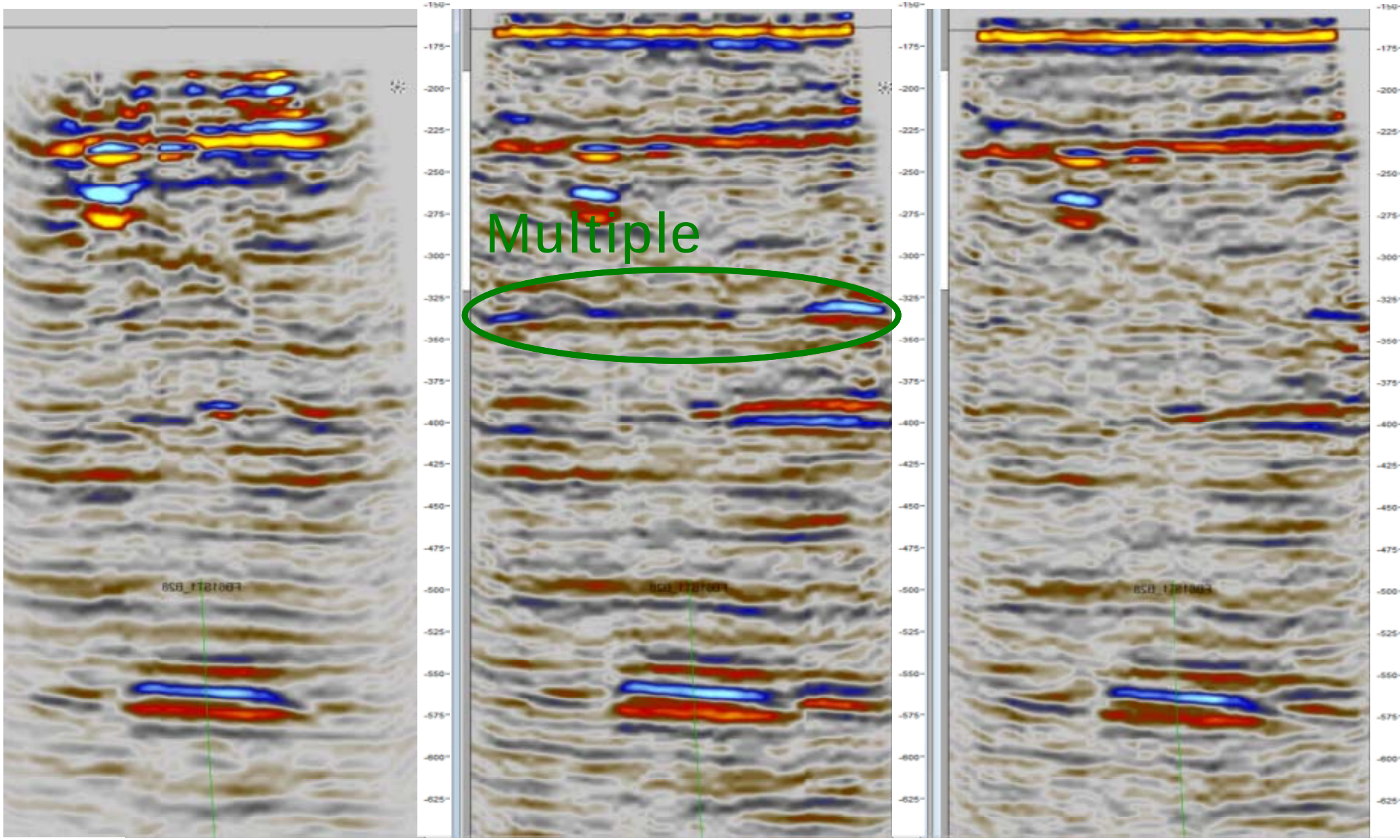


Postplot geometry

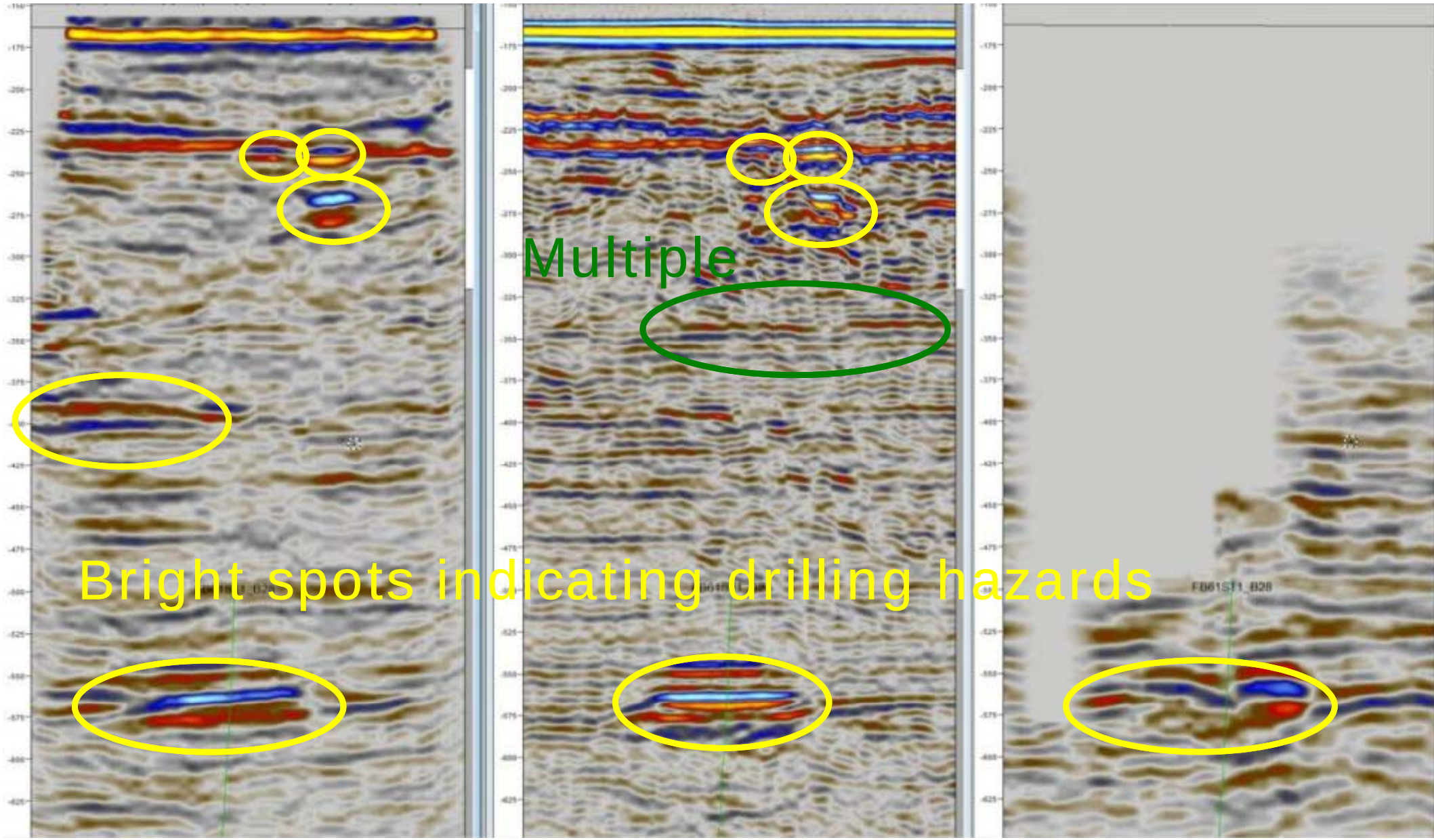
- **Node geometry—nominally hexagonal with offsets for seabed obstructions**
- **Shot geometry: close to desired spiral, but exact shot positioning was not required for coverage.**

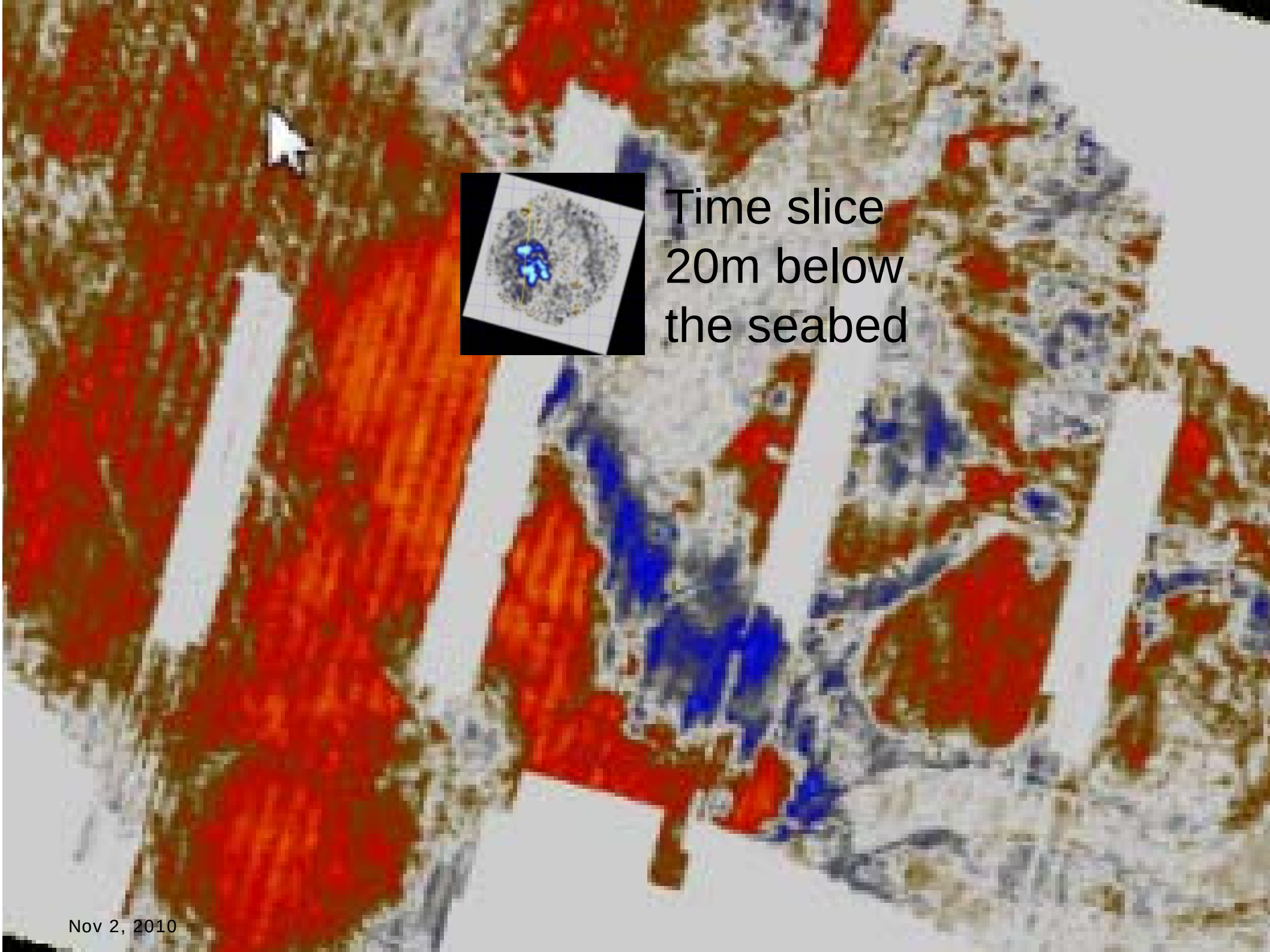


Up-going Mirror Mirror+Demultiple

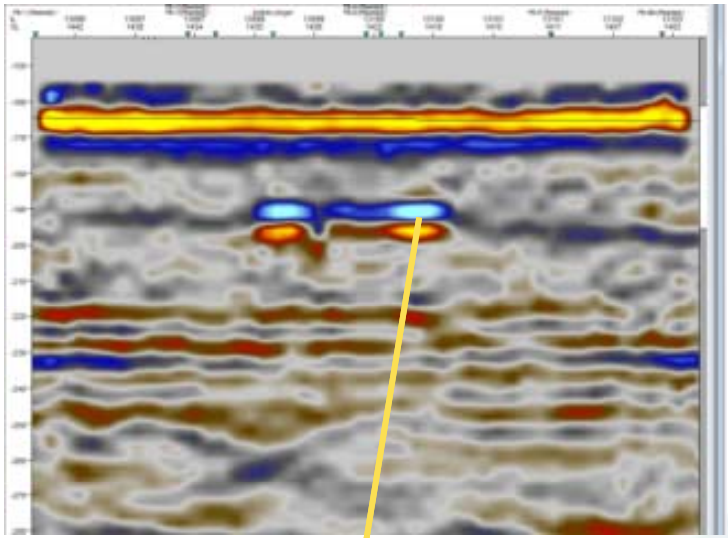


Nodes 3D Streamer 2D 3D Undershoot

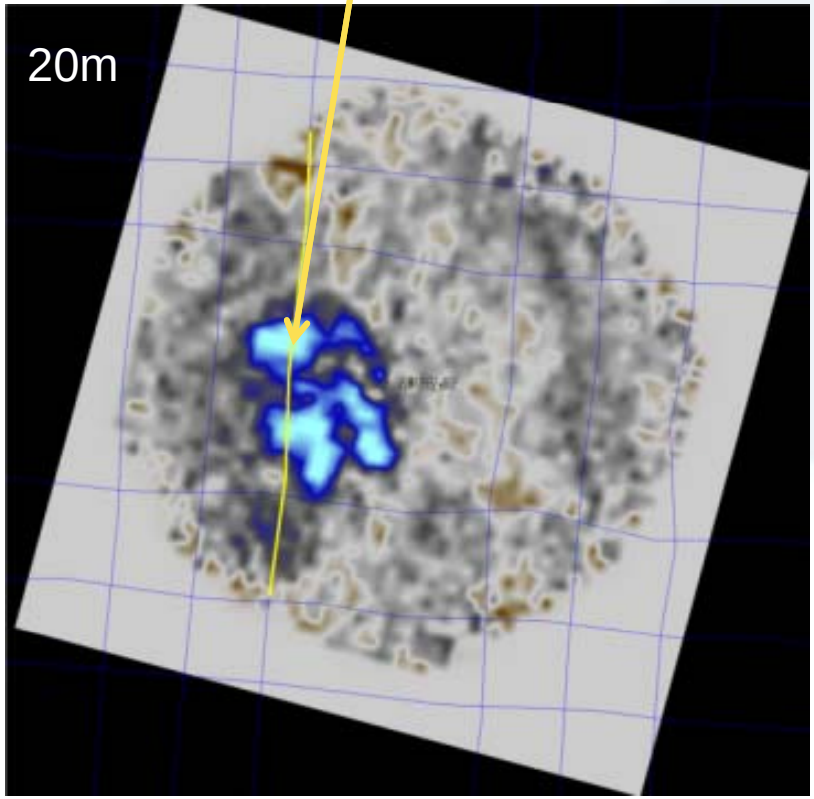


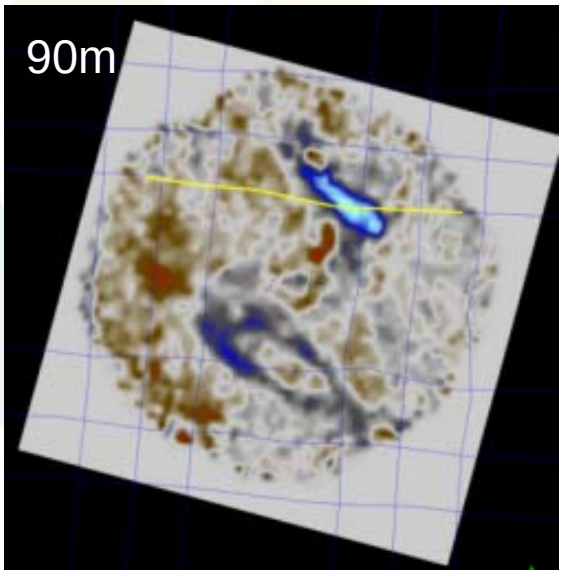

Time slice
20m below
the seabed
Nov 2, 2010

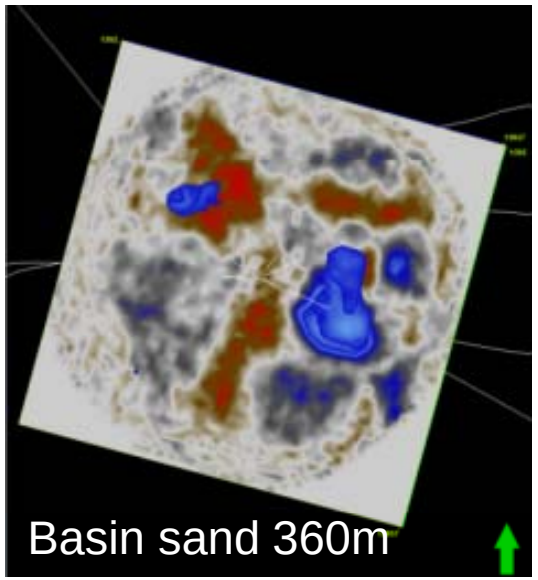
Hazards successfully imaged



- Down-going OBS data provides 3D image of hazards below platform as shallow as 20m below seabed







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Nyegga area (Haacke et al, Exley et al)

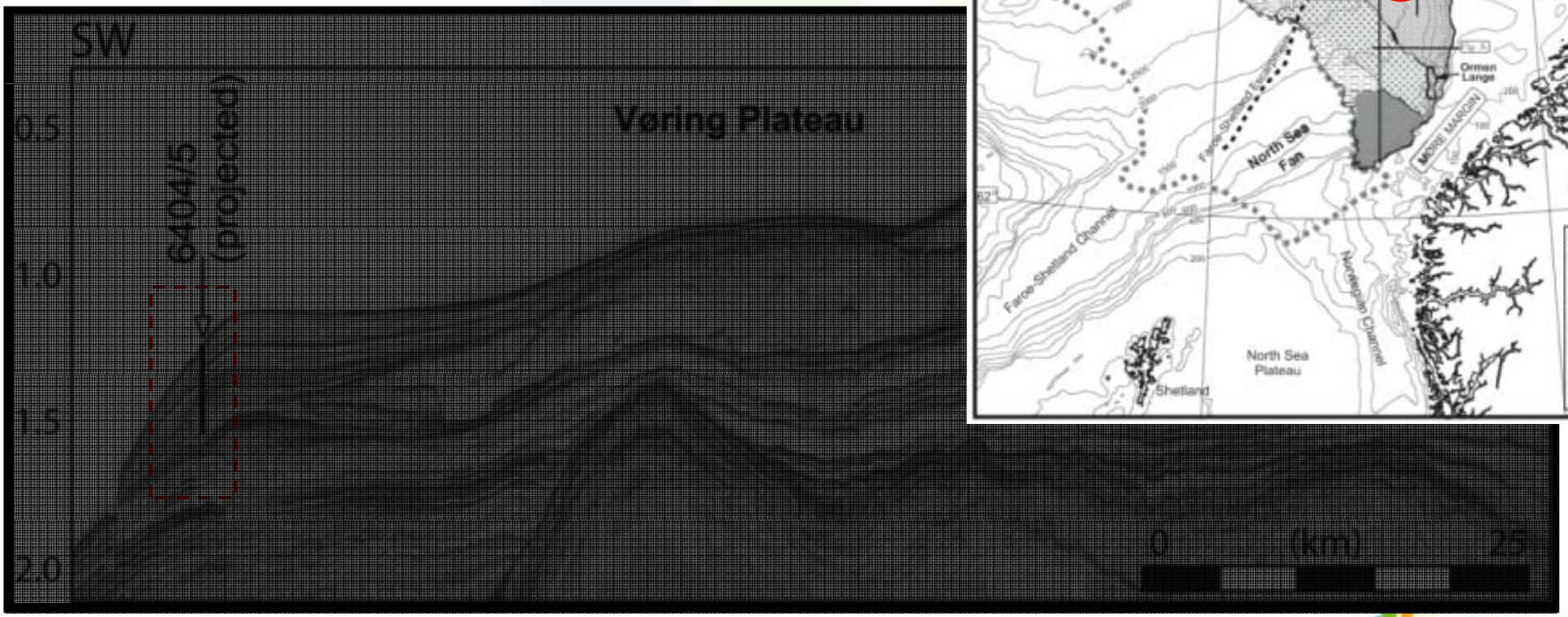
>> Northern headwall of Storegga Slide

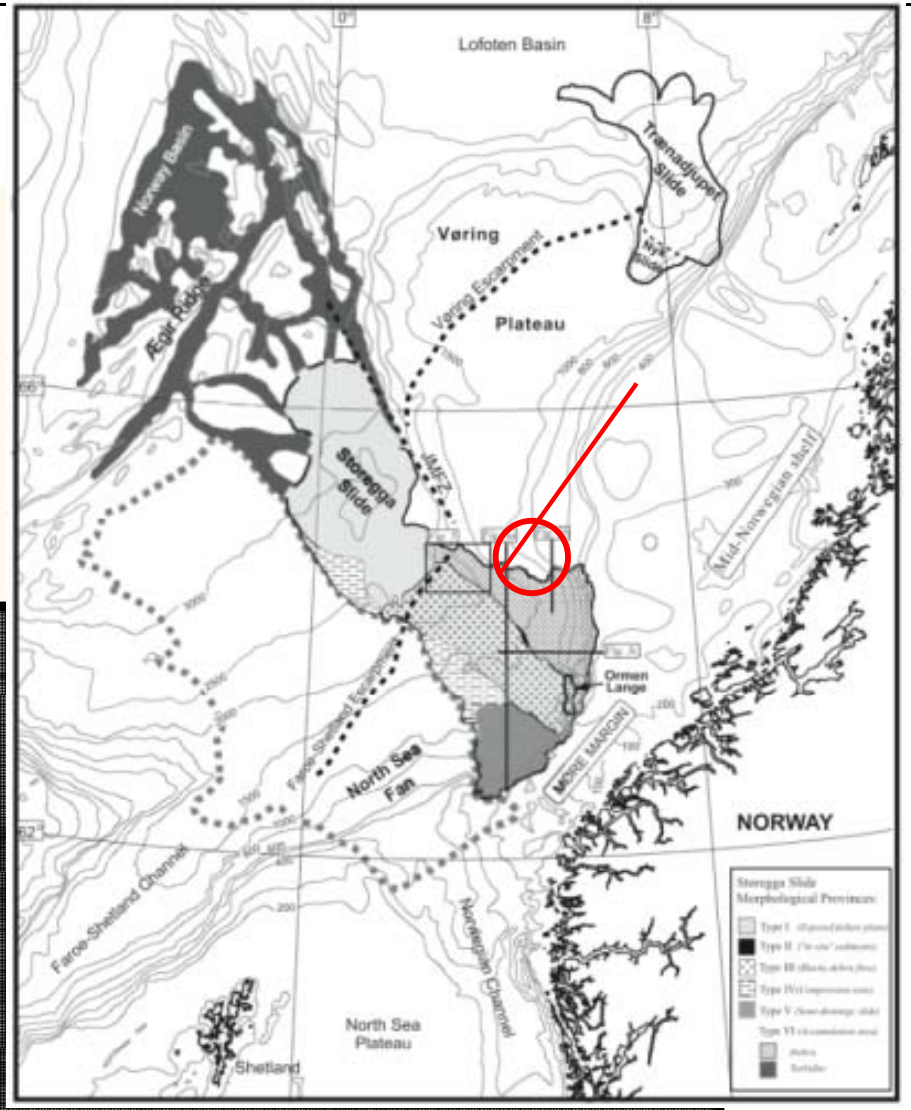
>> OBS array (PP and PS waves)

>> S-wave splitting (azimuthal anisotropy)

>> Overpressure (crack dilatation)

>> Slope collapse (landslide)





figures adapted from Sejrup et al. (2004)

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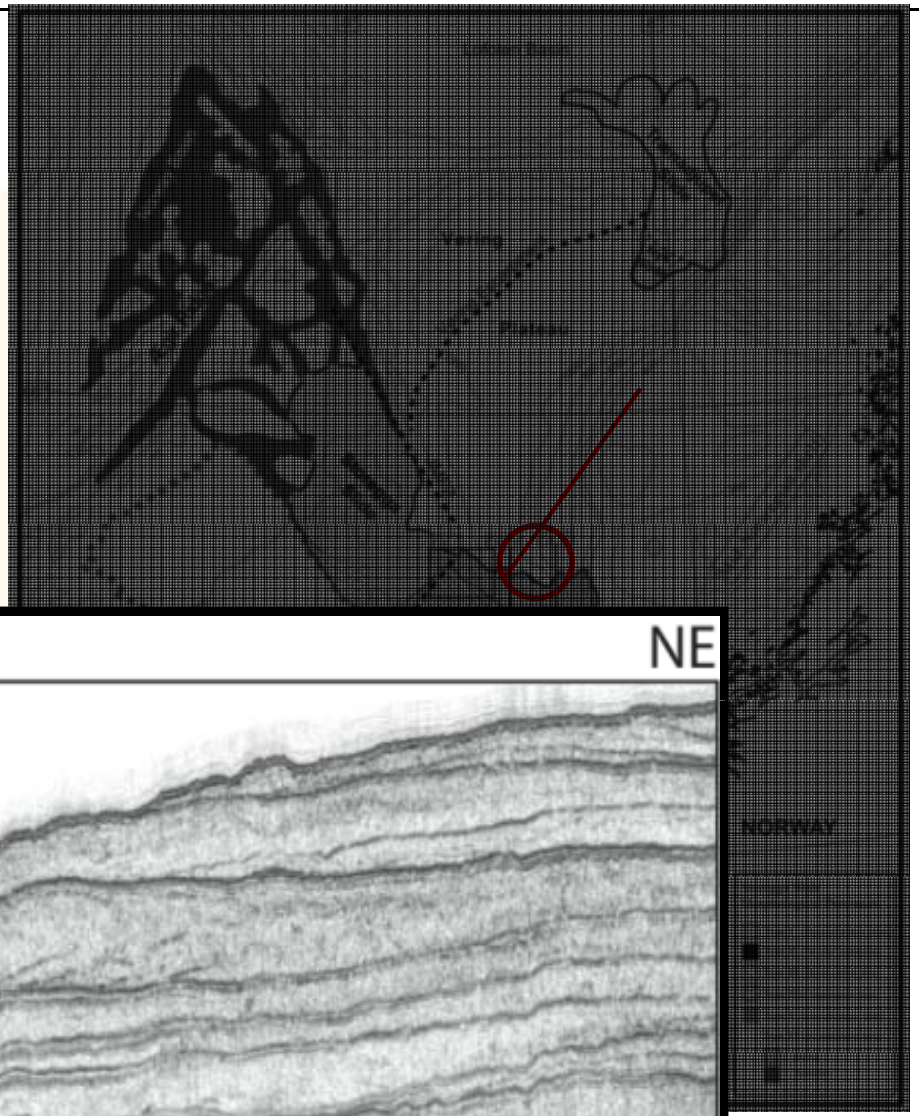
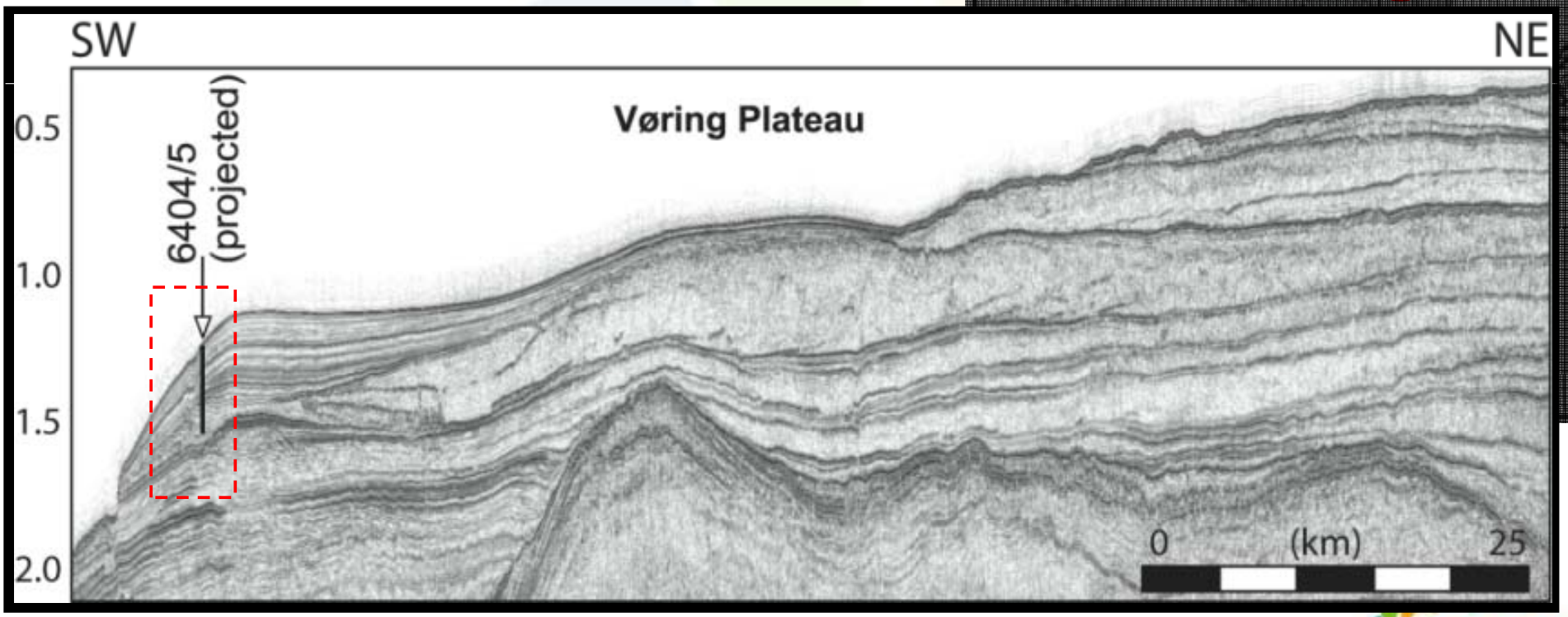
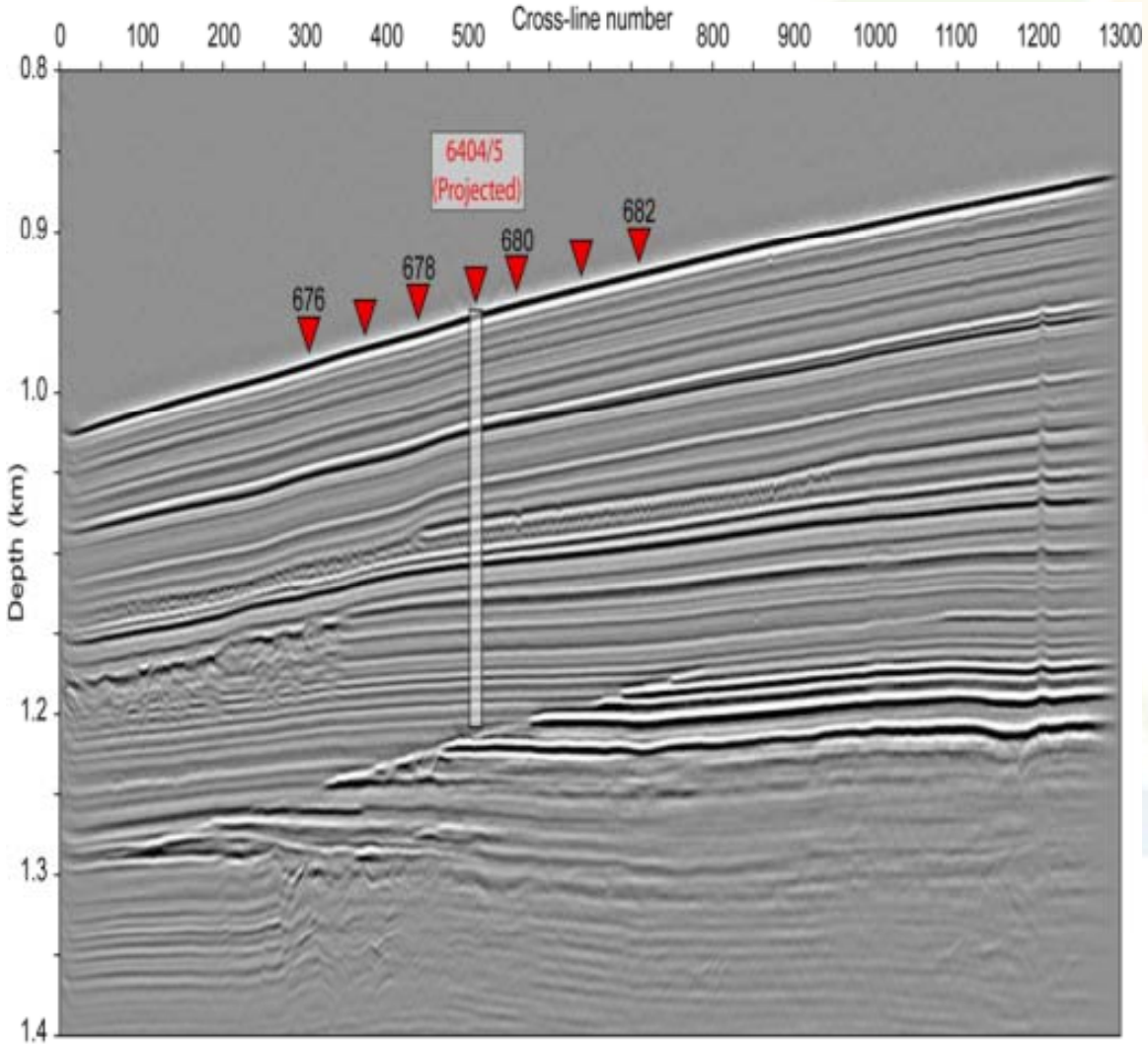


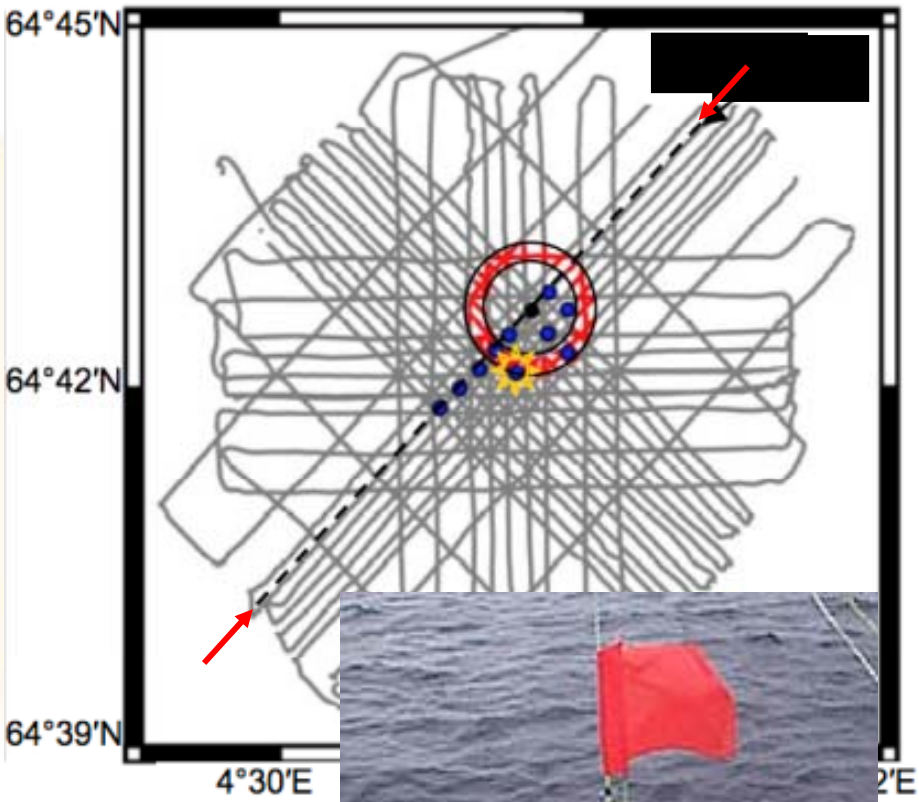


figures adapted from Sejrup et al. (2004)

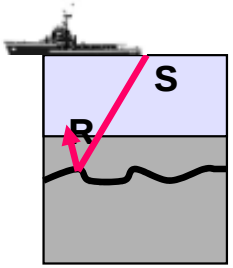
OBS data acquisition

>> 2 x 40 in^3 sleeve guns, 4 m depth
>> 400 m OBS separation
>> External (Carrack) phone

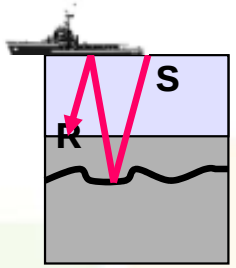




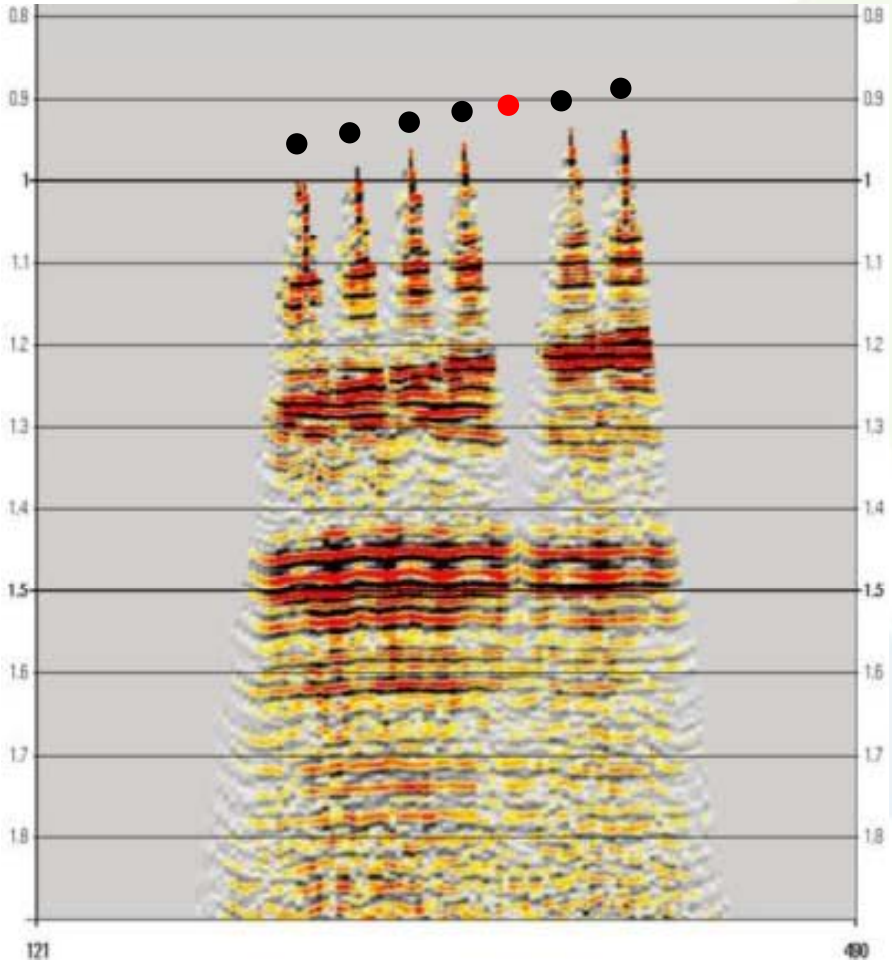
Mirror Imaging (P waves)

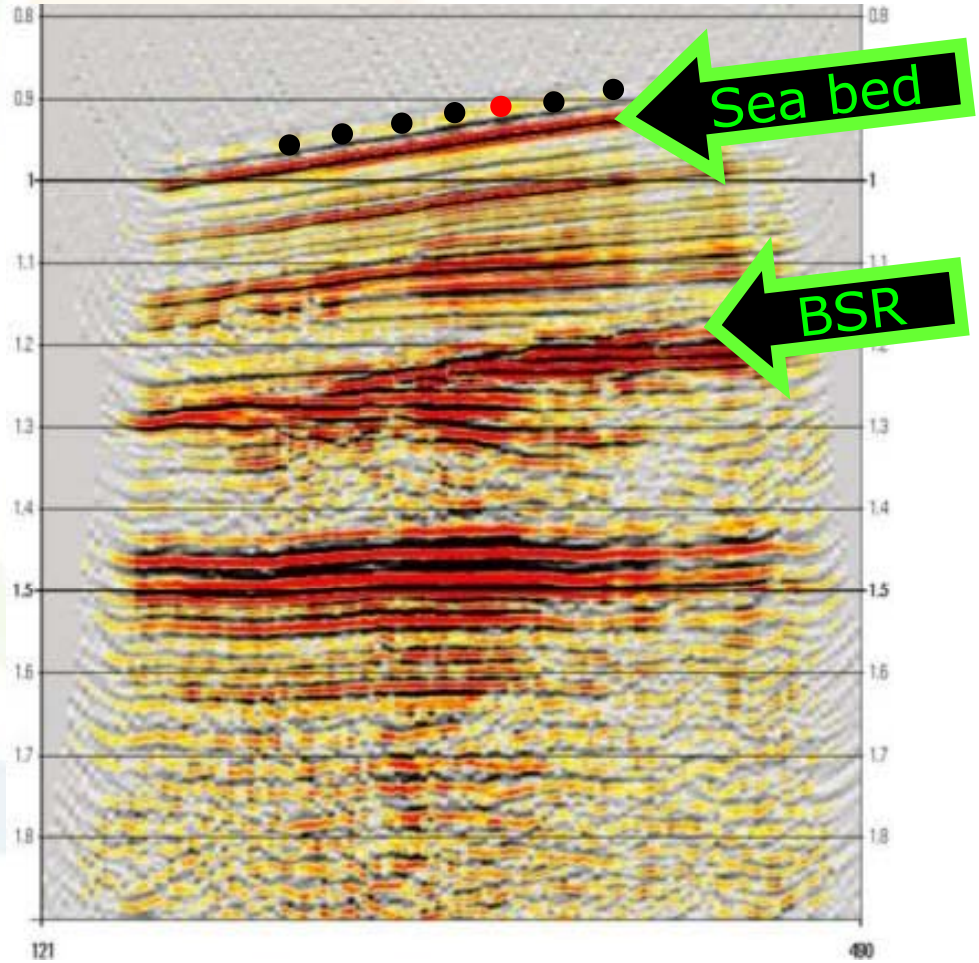


Up-going
(Conventional)



Down-going
(Mirror Image)





Credits: University of Birmingham SLA-OBS data

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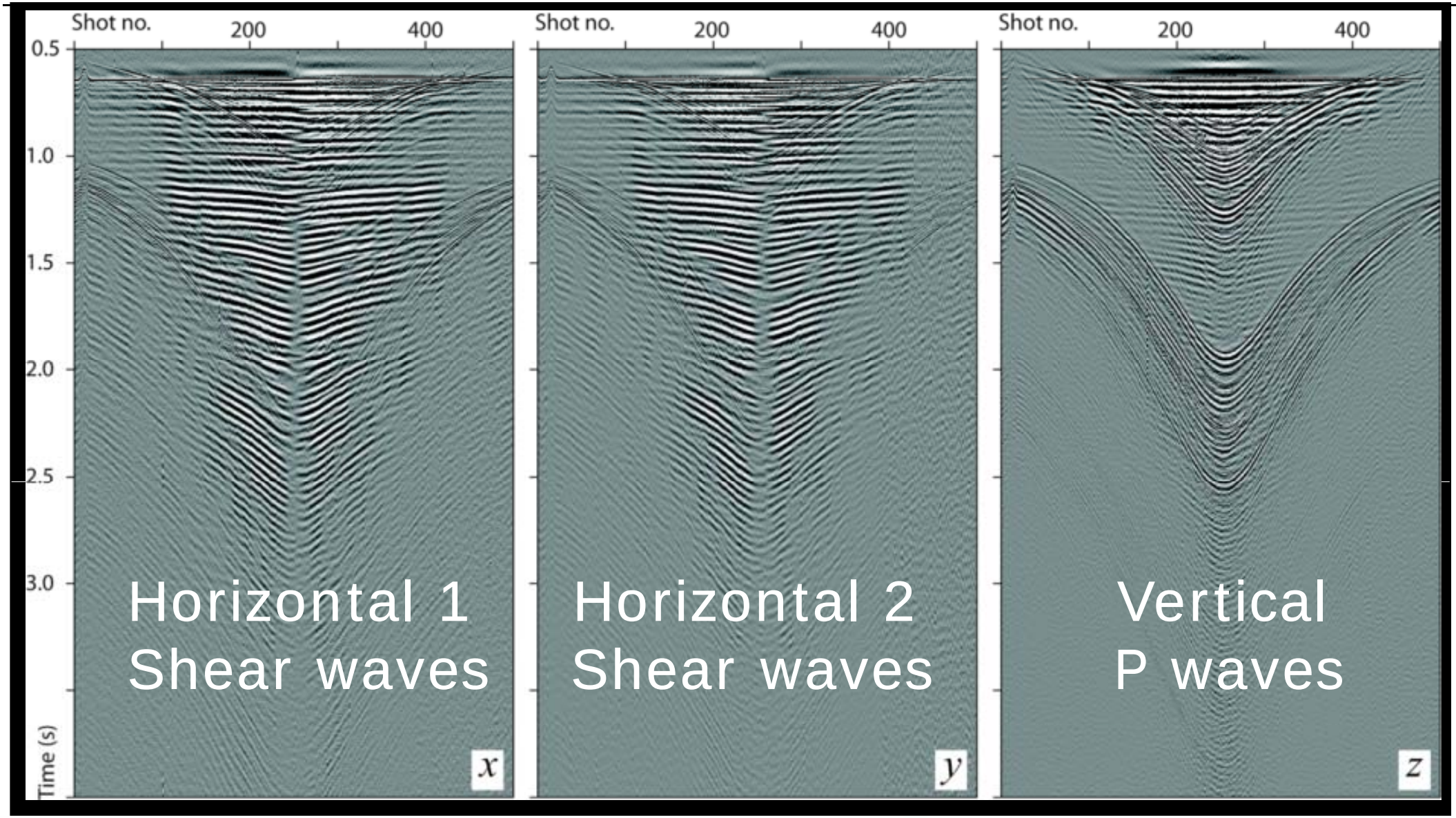
P and Shear waves recorded by the nodes (data after HMO)



>> traveltime reduction at water velocity

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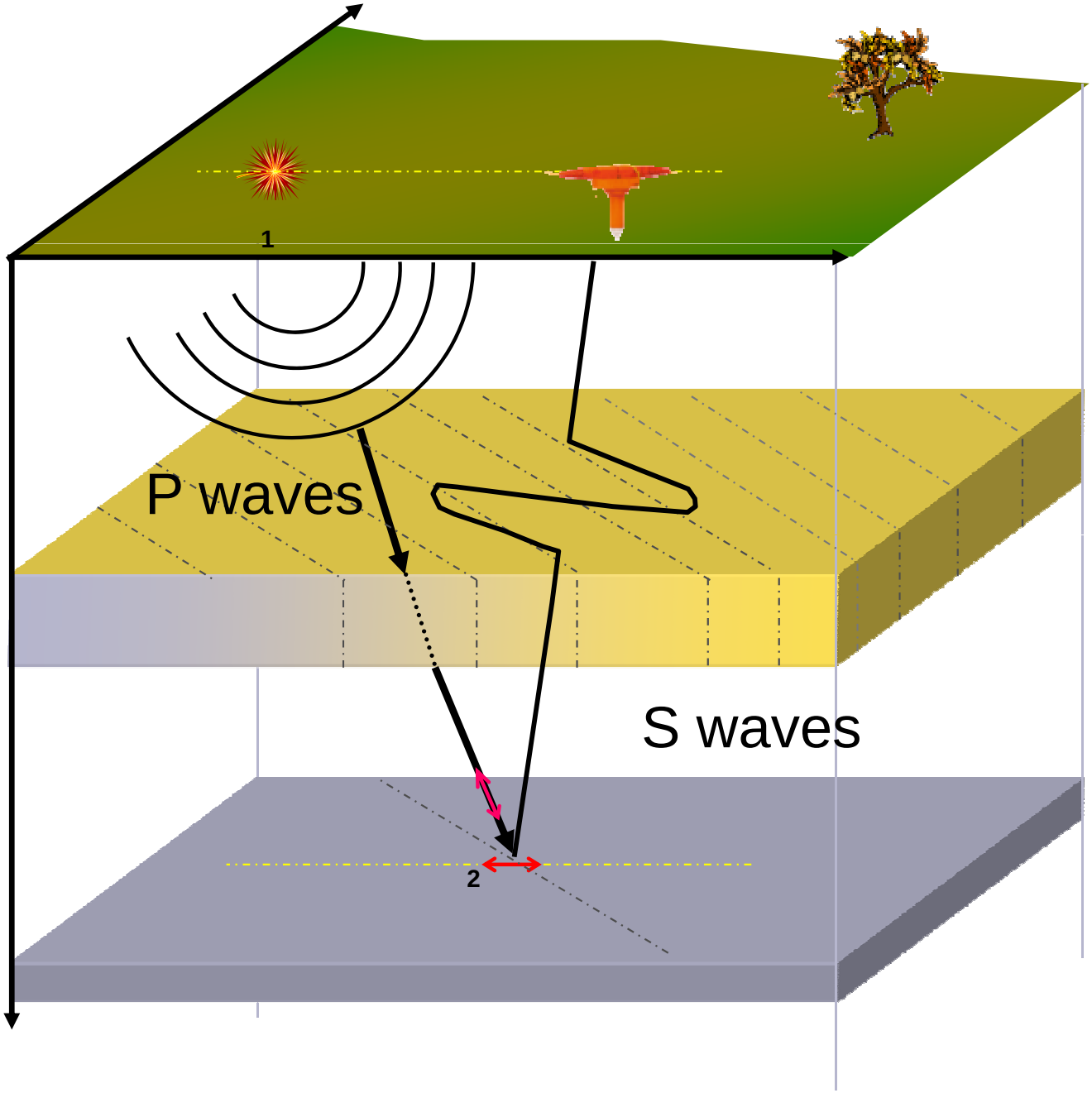
Converted waves



Converted PS waves

1. P down
2. Shear up

After many years of investment in developing shear sources we found that the best shear source is the P source

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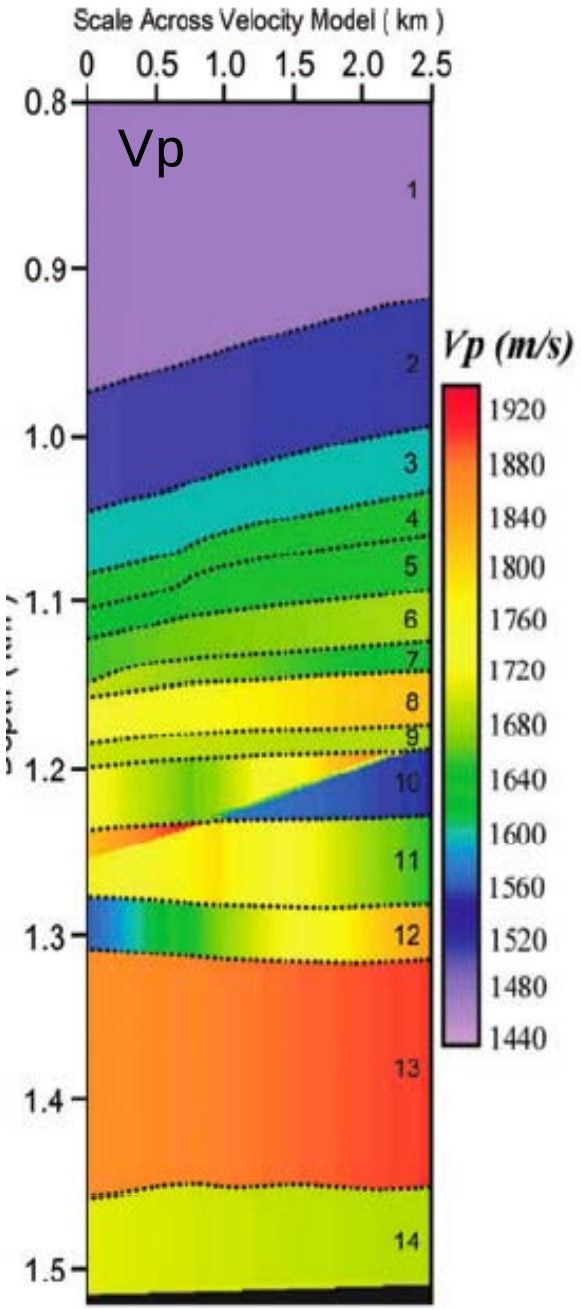
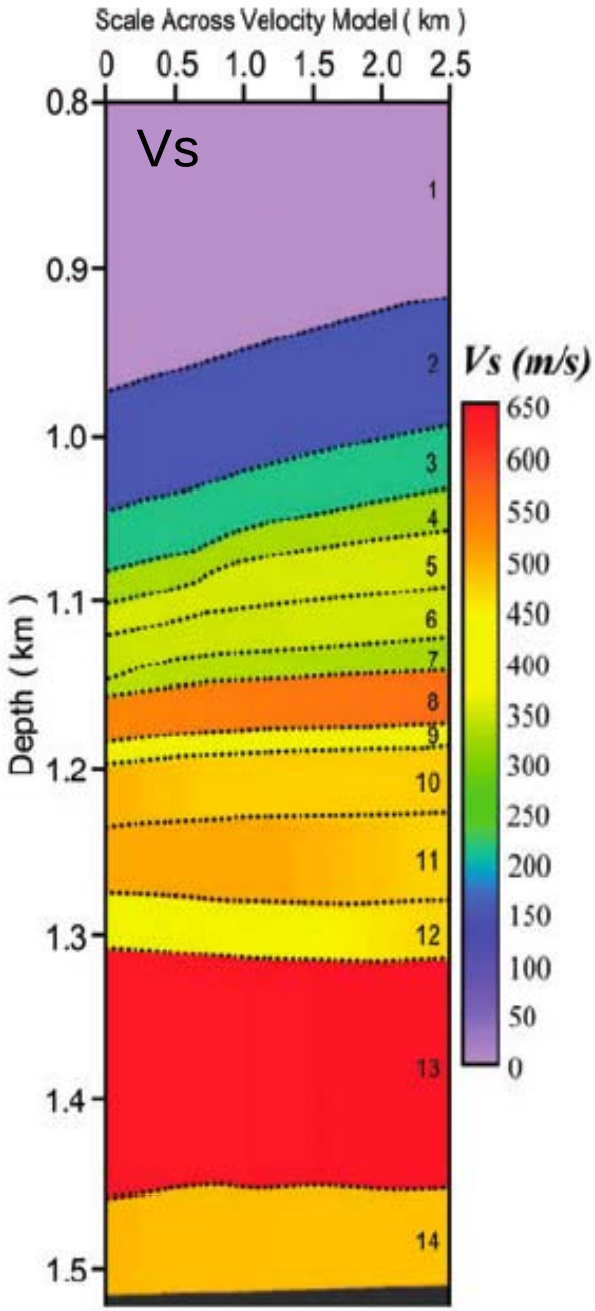
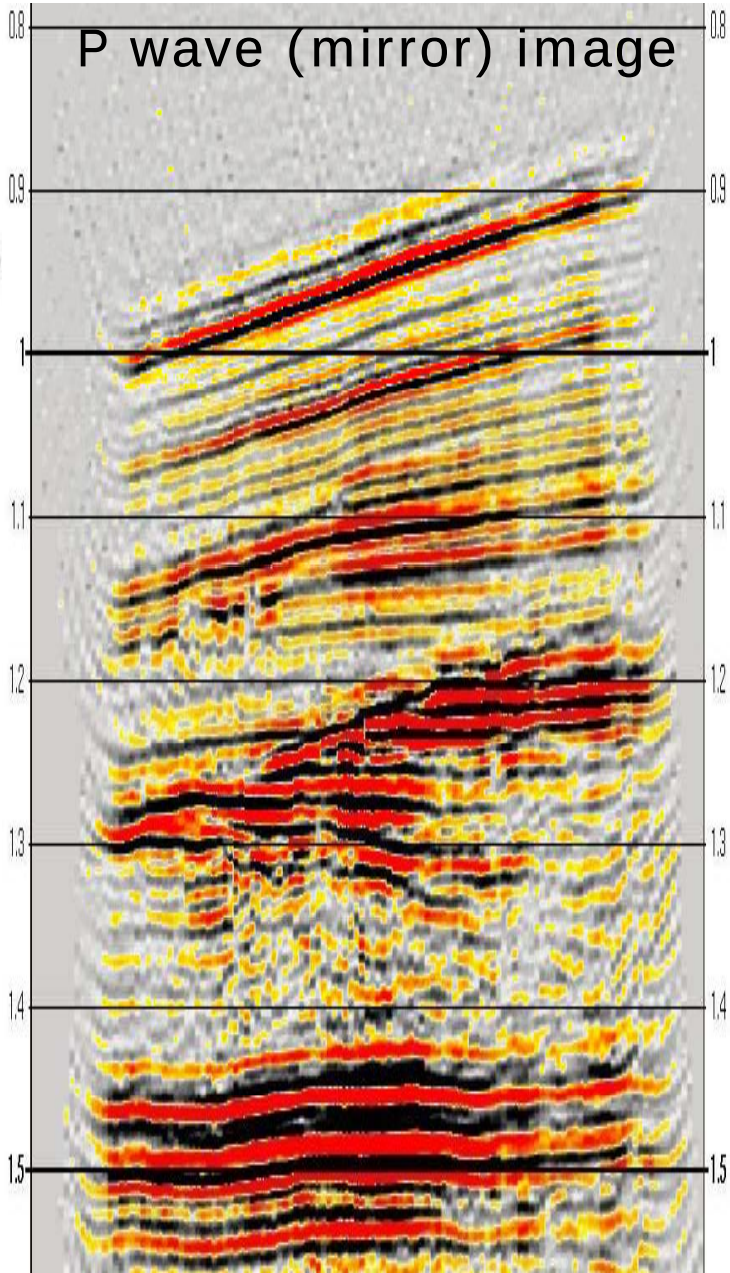
Nyegga: Vp and Vs velocity models from tomography



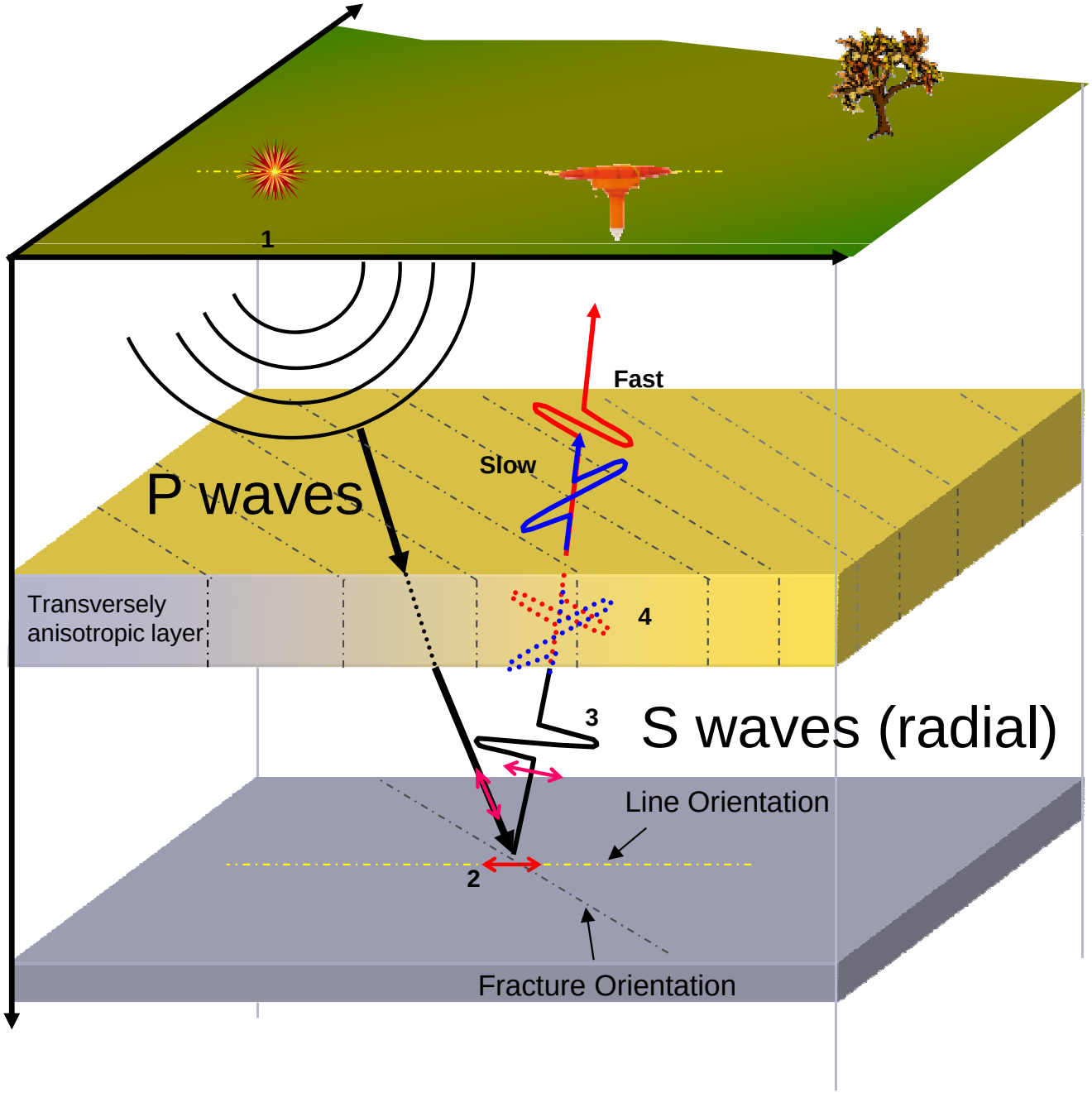


From Exley et al, 2010

From Grion et al, 2007



Shear Wave Splitting



Converted PS waves

- P down
- Shear up

The shear waves start going up in Radial polarity. As they propagate up they split to fast & slow $PS_{1\&2}$

- PS_2 is delayed
- PS_2 is attenuated

Analysis:

- ✓ **S_1 azimuth**
- ✓ **$\Delta t_1 / \Delta t_2$ times**
- ✓ **S_1 / S_2 attenuations**
- ✓ **PS AVOA**

SWS is more robust than shear wave imaging

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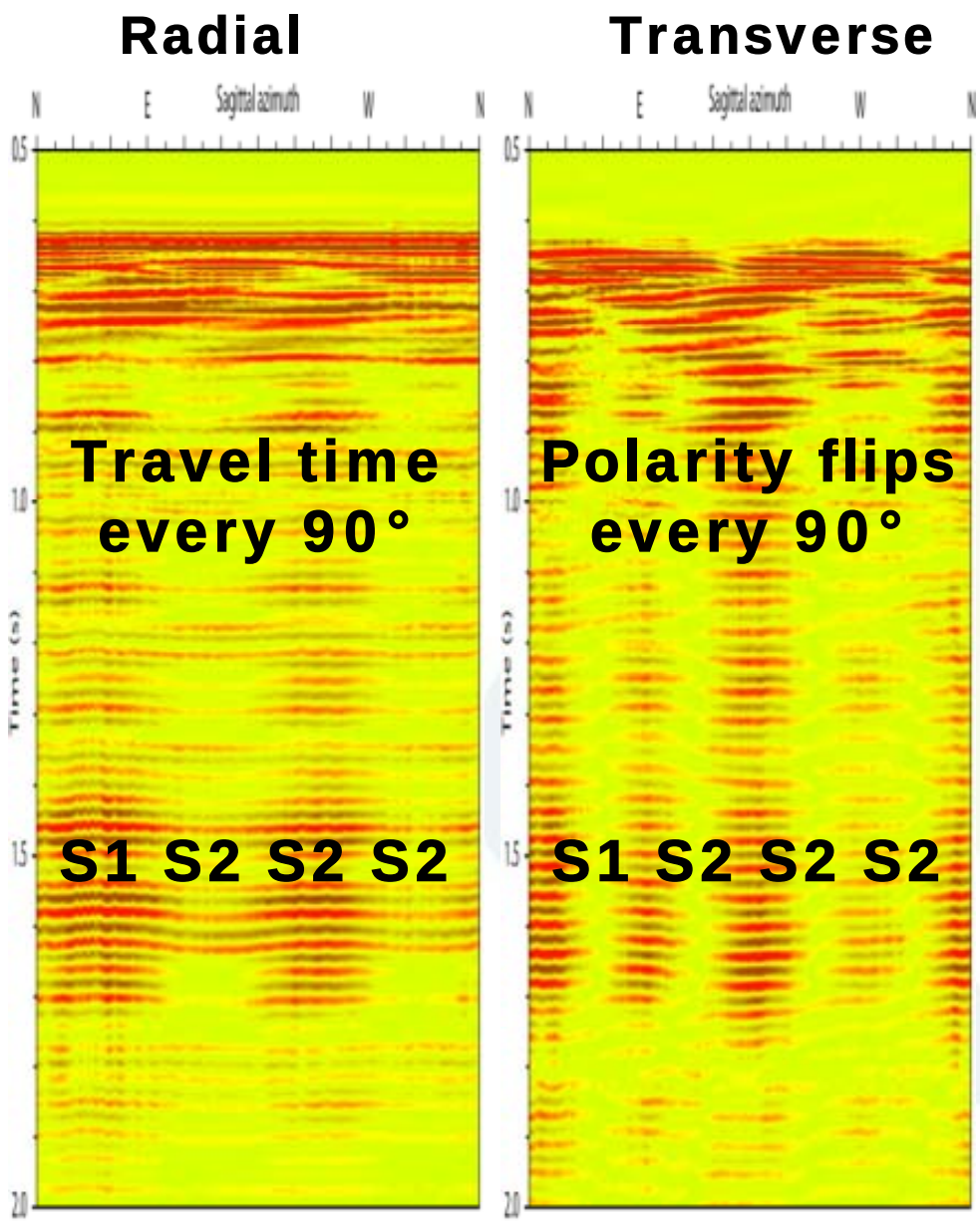
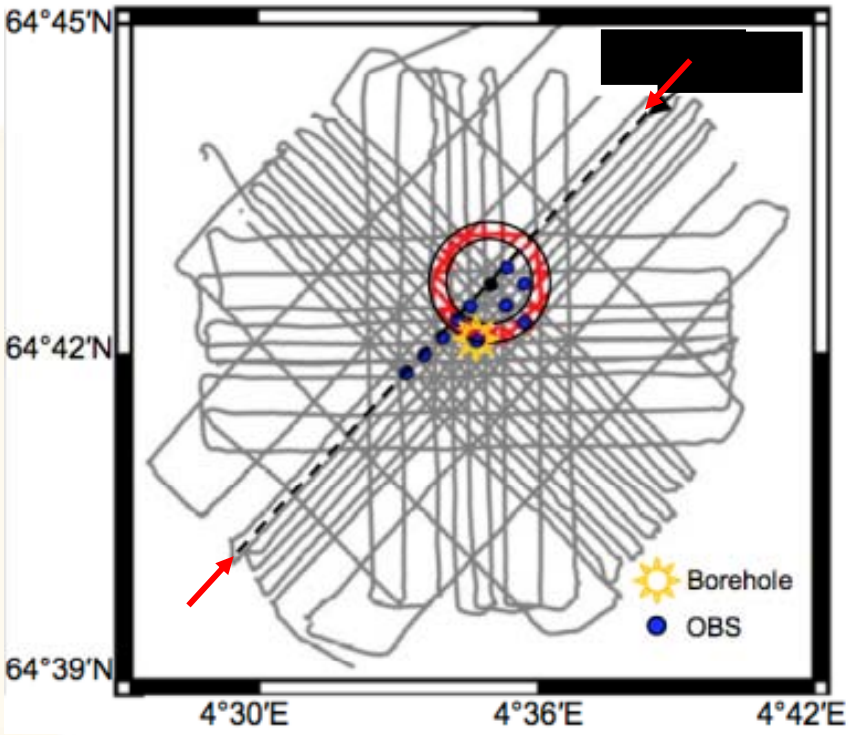
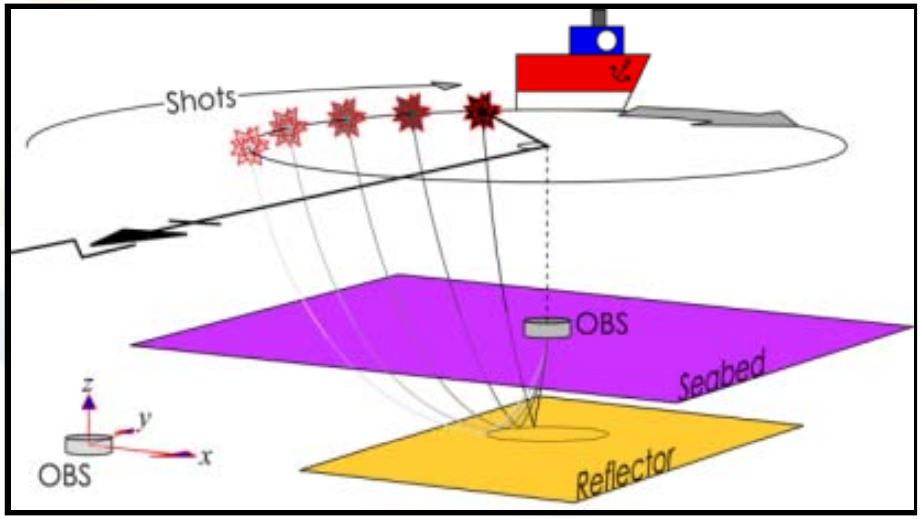
Shear wave splitting in Nyegga



Haacke et al, EAGE 2010





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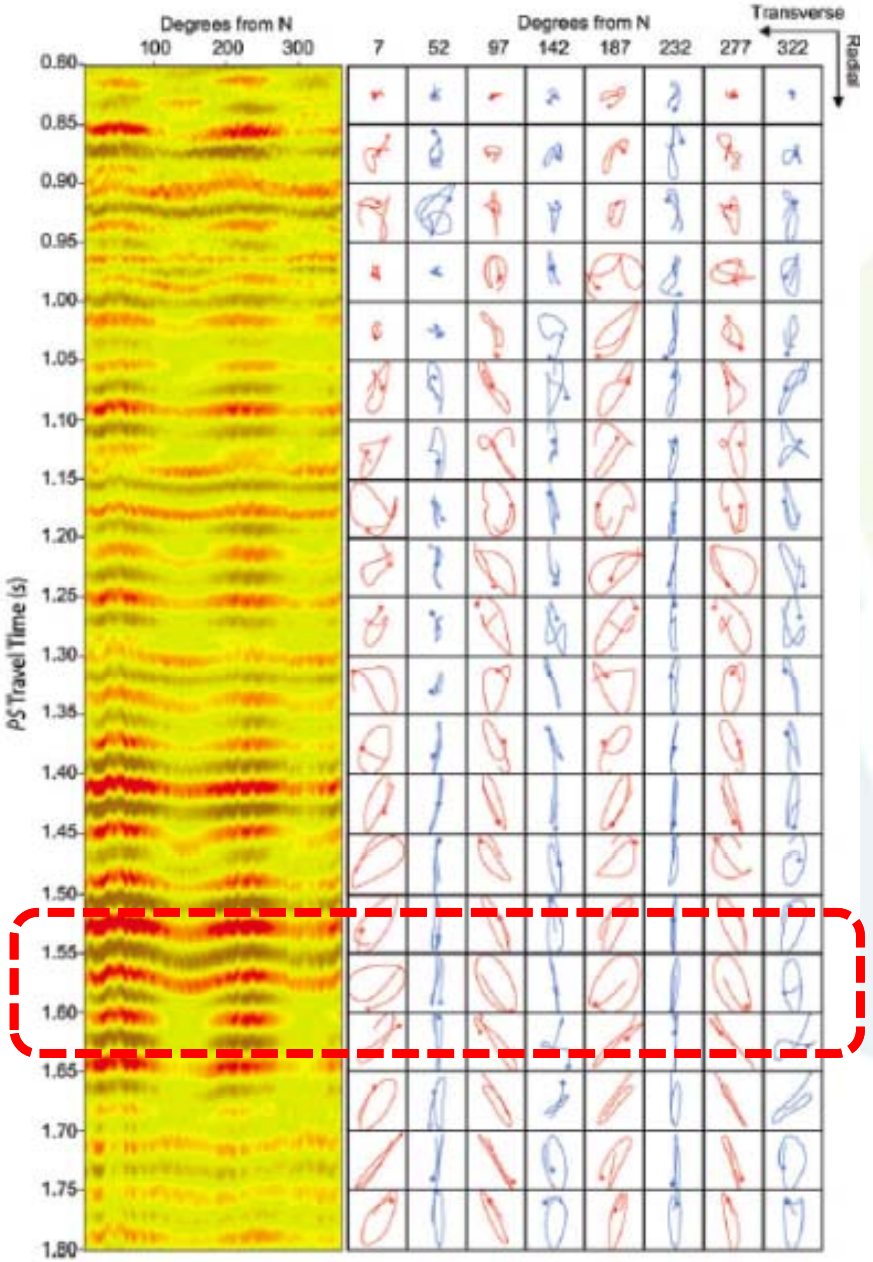
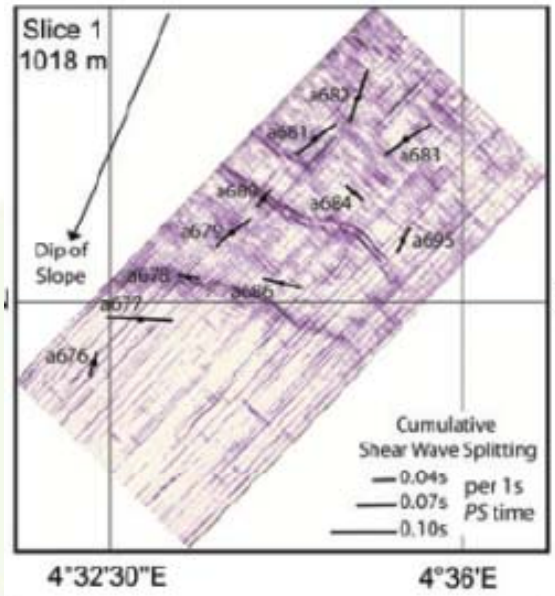
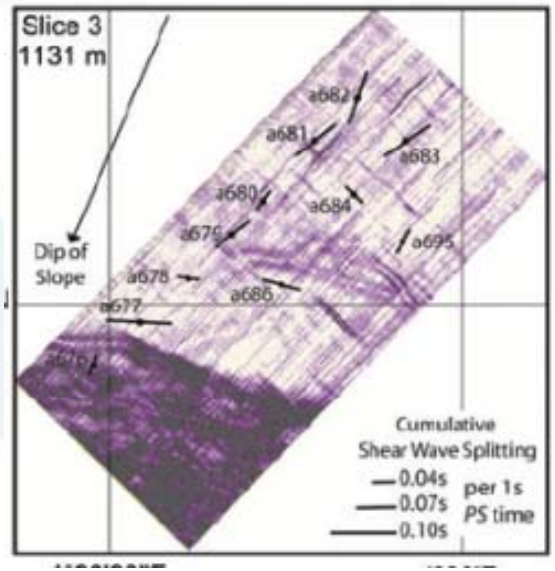
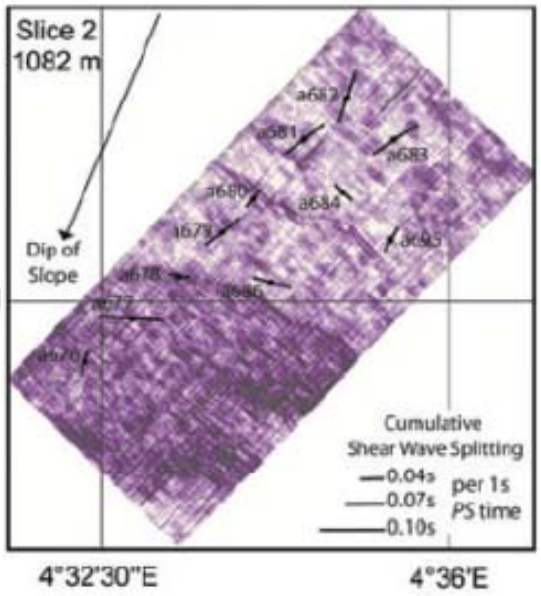






64°42'N



S1 direction and SWS magnitude overlayed on (P wave) coherency time slices

Exley et al, 2010

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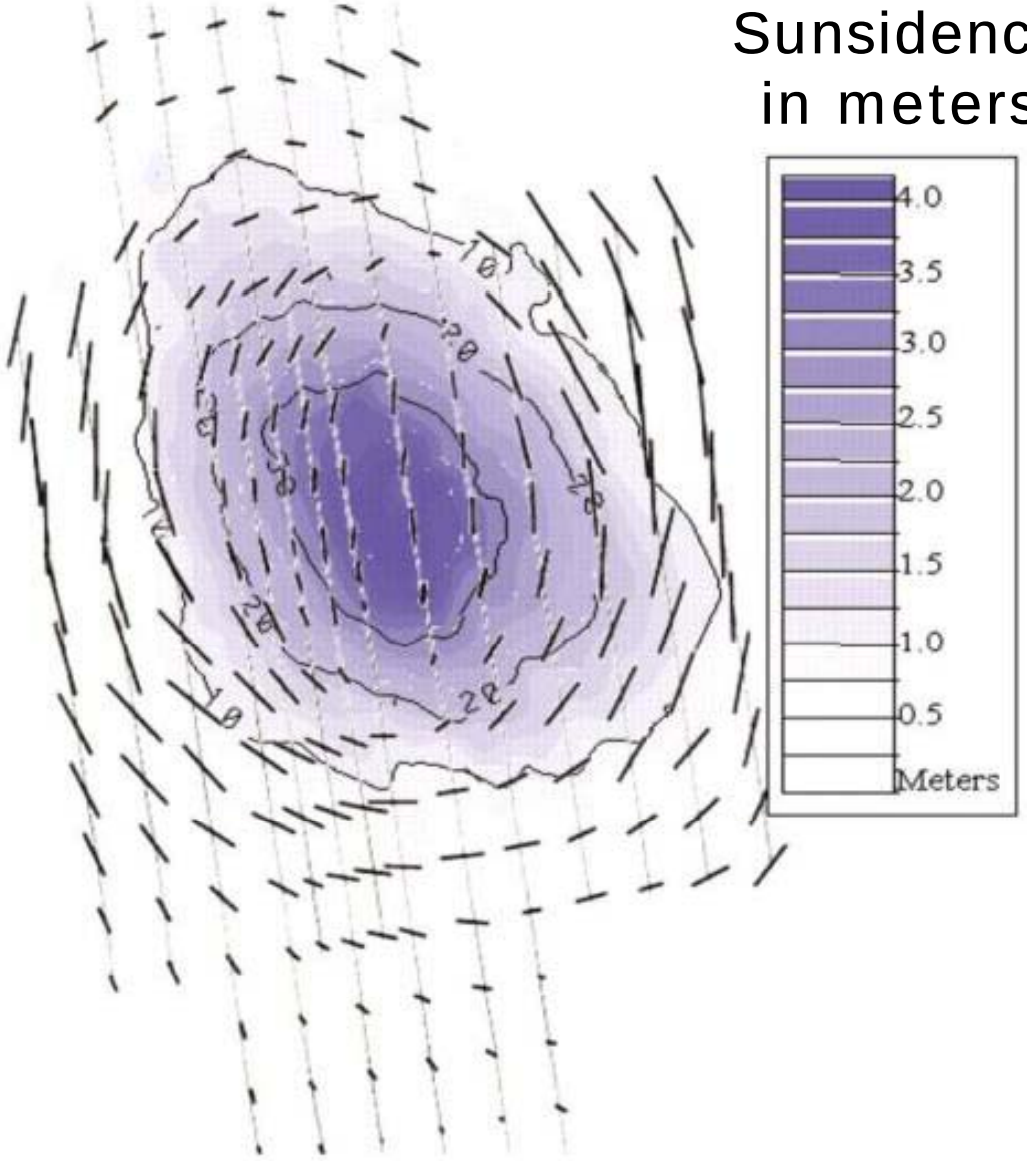
Shear wave splitting and subsidence in Valhall

- 4C OBC data
- Azimuthal anisotropy induced by subsidence due to production.
- Similar effect observed in Gryphon, Lomond, Ekofisk, …

Azimuthal anisotropy from the Valhall 4C 3D survey
Olofsson, Probert, Kommedal, Barkved
December 2003 tLE



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Content

Geophysical methods

- Surface Towed Streamers
  - They can be broad band
- Ocean bottom nodes
  - P waves
  - Converted PS waves

Geohazard applications

- Shallow Gas
- Gas Hydrates and seabed slides
- Subsidence
- Overpressure
- ...

Warning: this talk is a mile wide and a foot deep

(but in metric units)

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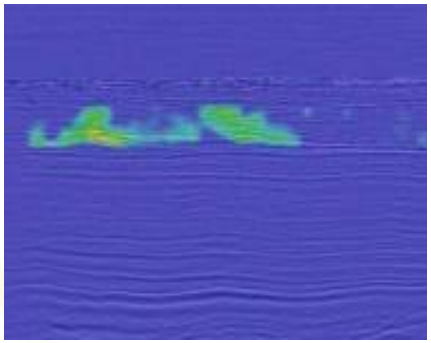
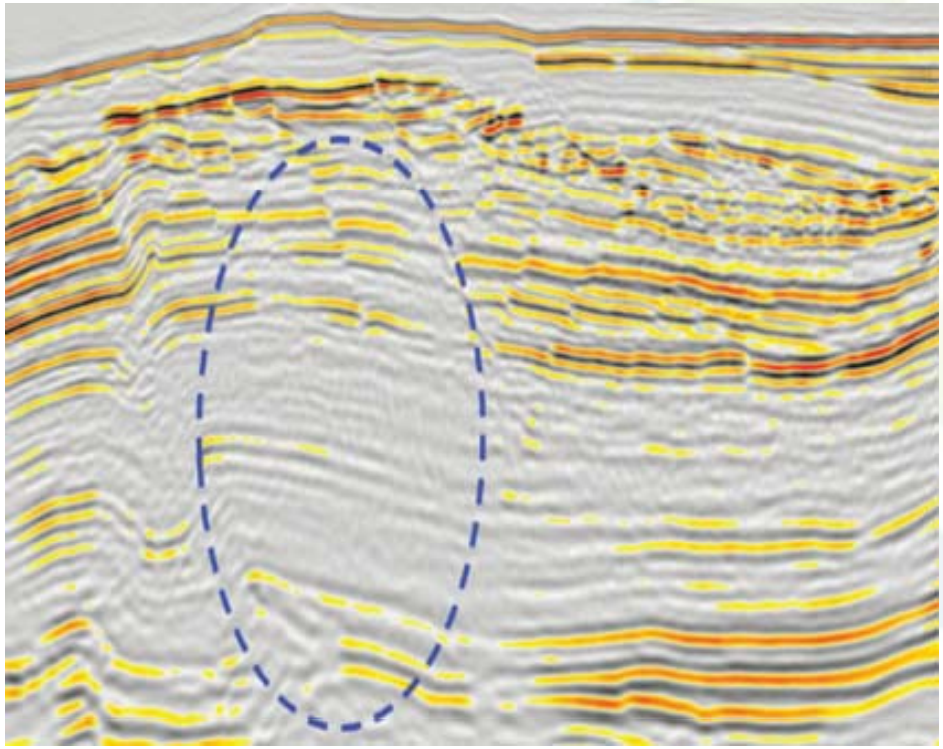
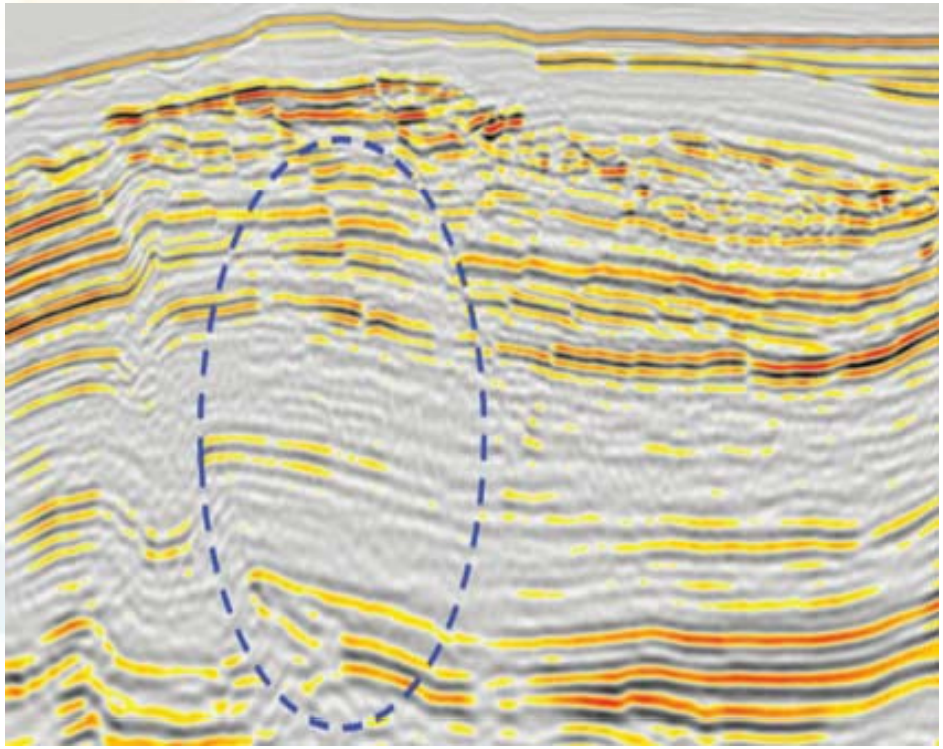
Tomography of gas hydrates in deep water GOM

- Q-compensating RTM
  - The Gas hydrates are over burden anomalies
  - Tomography to improved imaging under the hydrates
  - By product: velocity+Q model of the hydrates







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Integrated & Simultaneous Seismic and Site Surveys

The M/V Duke

- 10km solid streamer
- 4280 cu.in. Gun Array
- Sidescan sonar
- Sub-bottom profiler

OBN (P&PS, active+passive)

- Trilobit: 1000 nodes containerized crew 2Q2012

Data Processing

- Combine all methods
- Shear waves analysis

Applications

- Drilling Hazards
- Subsidence
- Gas Hydrates
- …

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