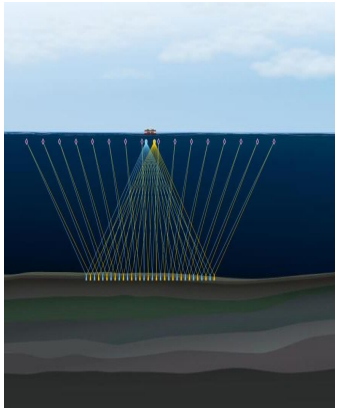
# Optimizing quality and efficiency in shallow water acquisition environments

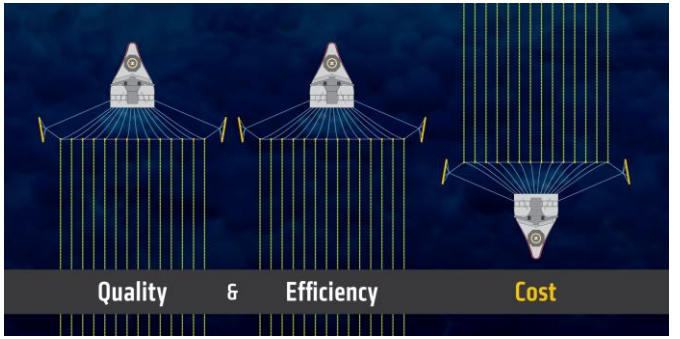
*Eivind Frømyr, Chief Geophysicist, Marine Contract*

23. February 2017

# Shallow water marine seismic acquisition

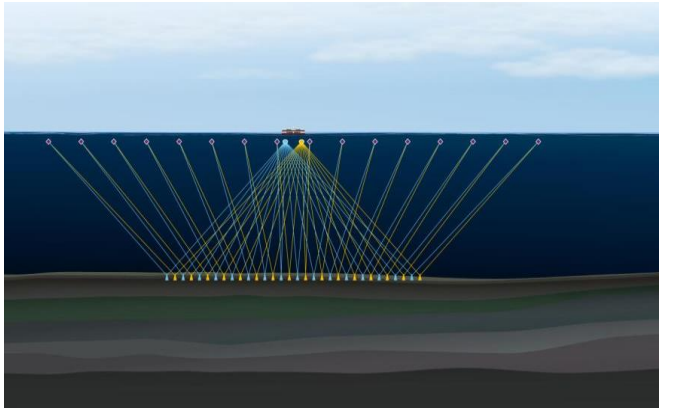
Narrow






BUSINESS DRIVERS

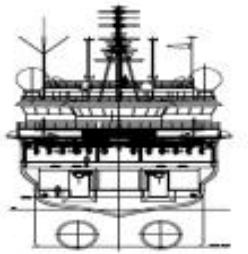
Wider



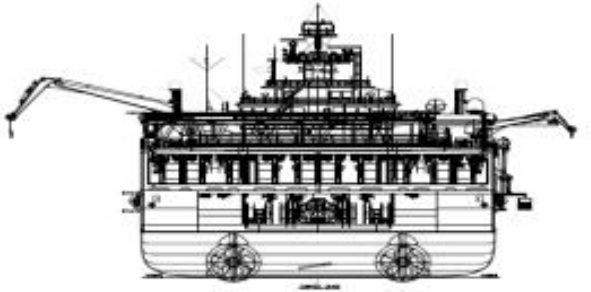

Vessel Technology
Streamer Technology
Processing Technology

# Outline

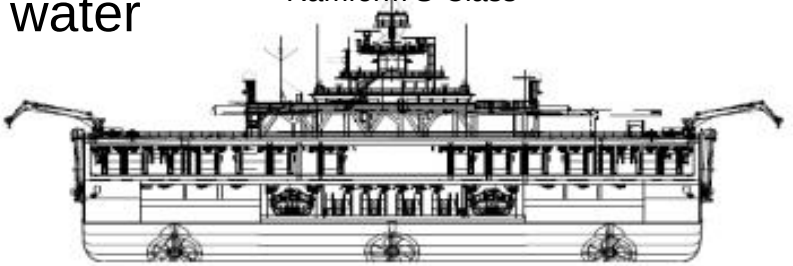
- Introduction
- Efficient acquisition – The vessel platform
  - The efficiency factor
  - The challenge
- The streamer platform
  - The efficiency factor
  - The quality factor
- Imaging with the dual wave-field
  - The principle
  - Mitigating the acquisition challenge in shallow water
- Summary and Conclusions



Conventional vessels



Ramform S-Class



Ramform, Titan

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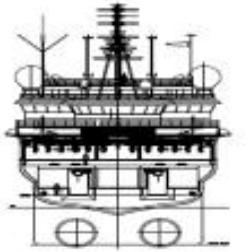

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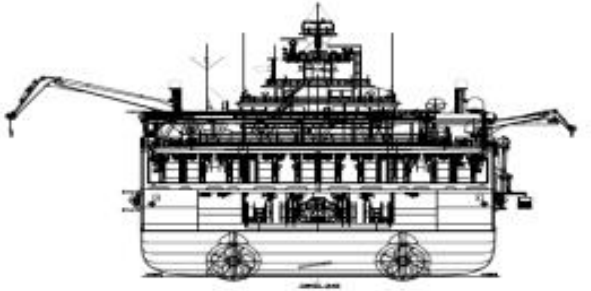

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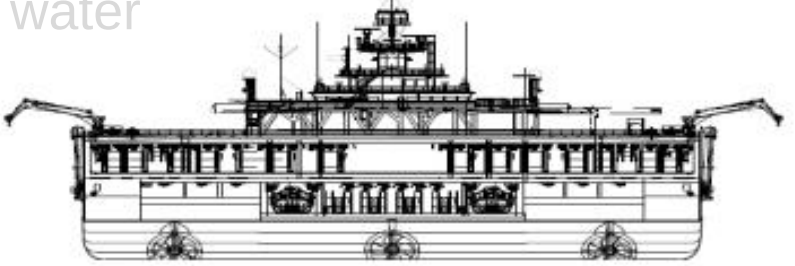


Ramform, Titan

# Wide tow – The Efficiency Driver

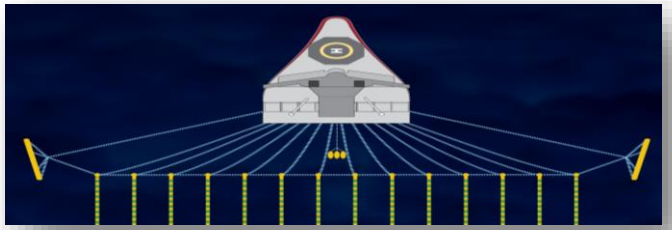

Up to 18 Streamers @ 100m, Up to 24 @75m or less

# Titan Back deck – 70m wide

**24 x 12000m Streamers**
**16 x lead-in winches**

**Plenty of space for efficient and safe deployment and retrieval of multiple streamers**

# Increasing Productivity: Deflector Upgrades to Deliver Wider Spreads





Baro 412 – 12m x 5m; 4 foils

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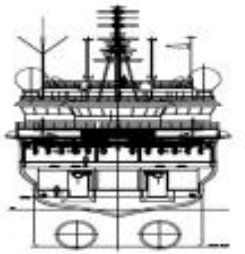

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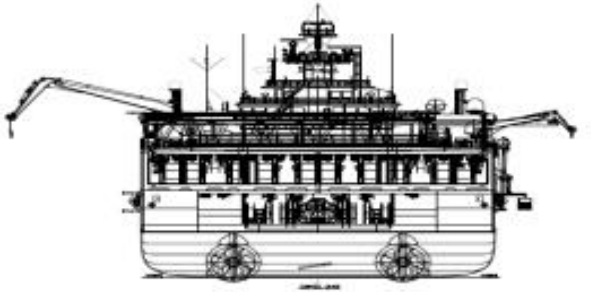

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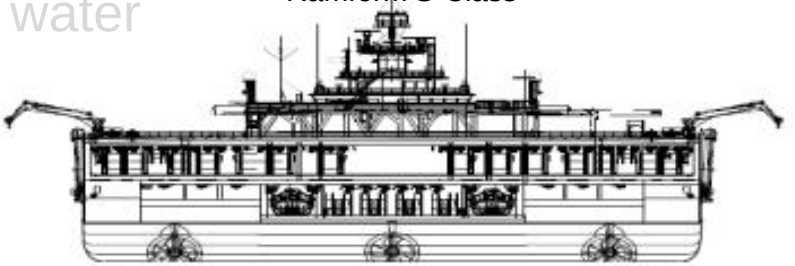
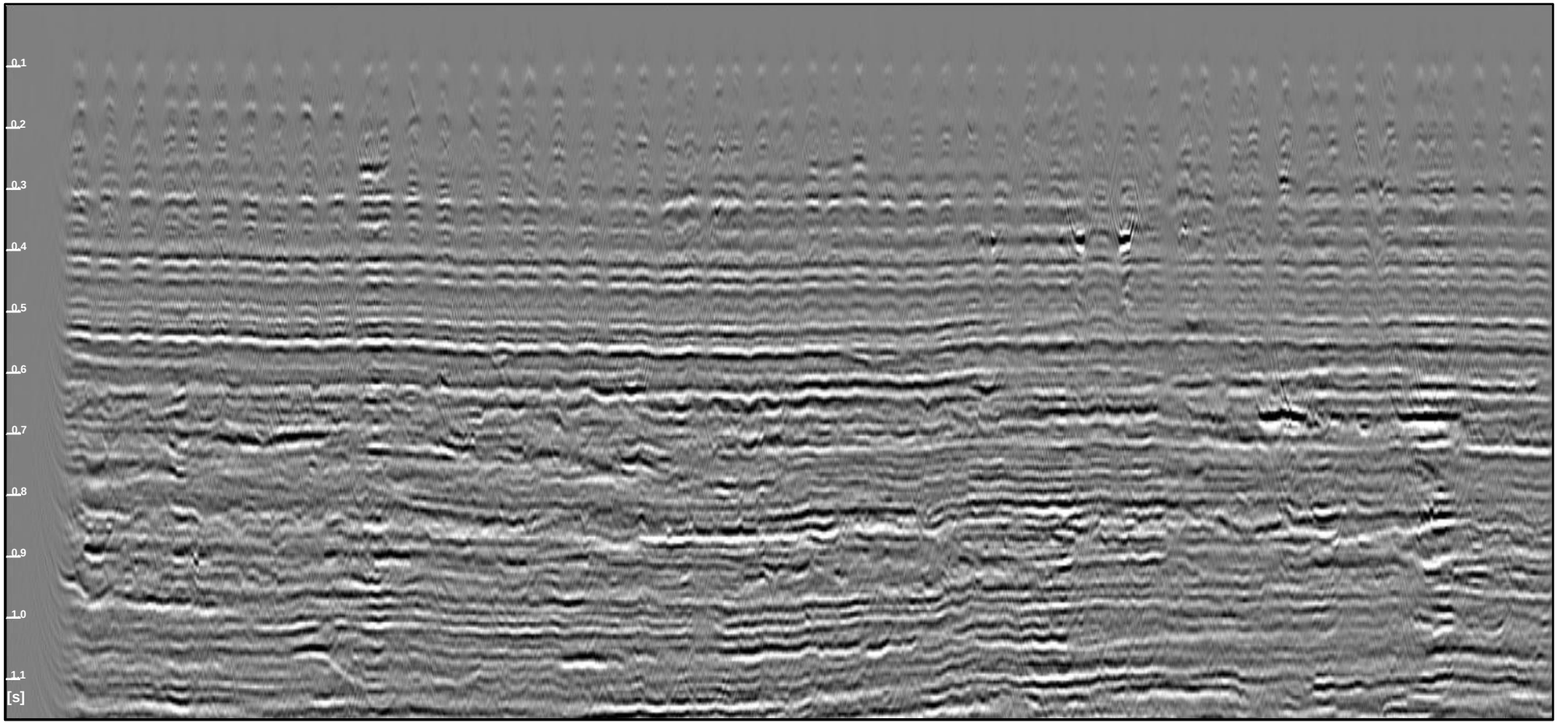
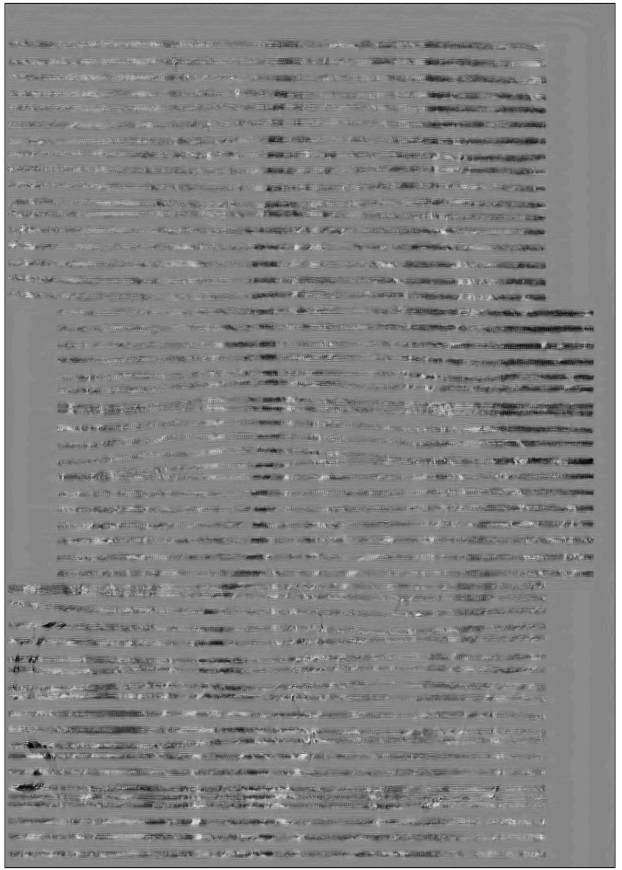


Ramform, Titan

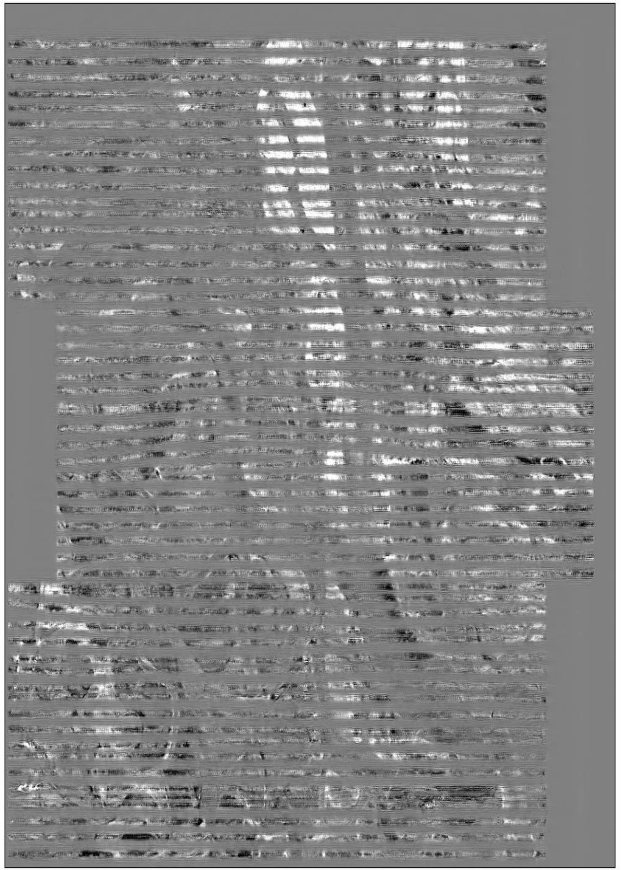
# Wide Tow in Shallow Water – Cross line – Illustrating the impact of Critical Angle



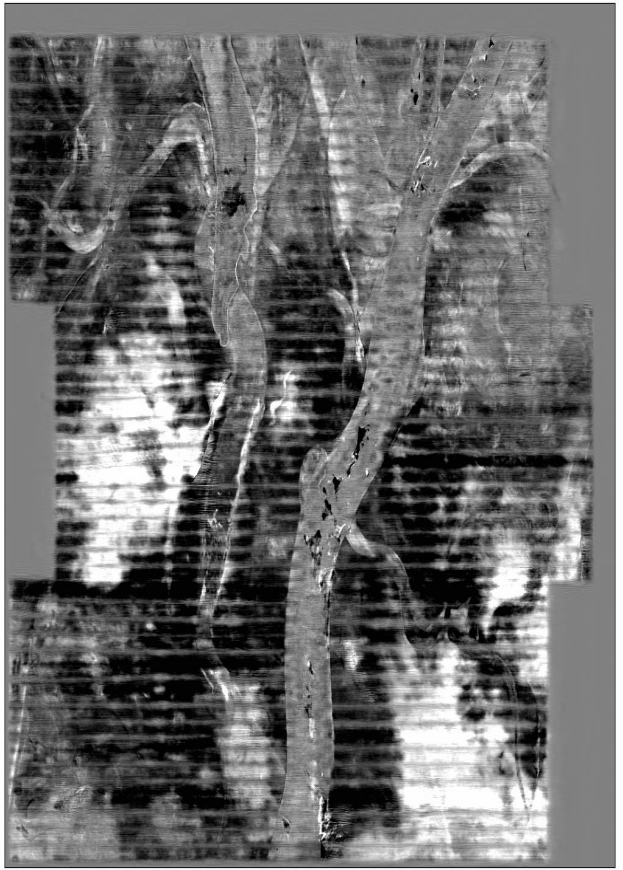
# Footprint with Wide Tow in Shallow water



105m

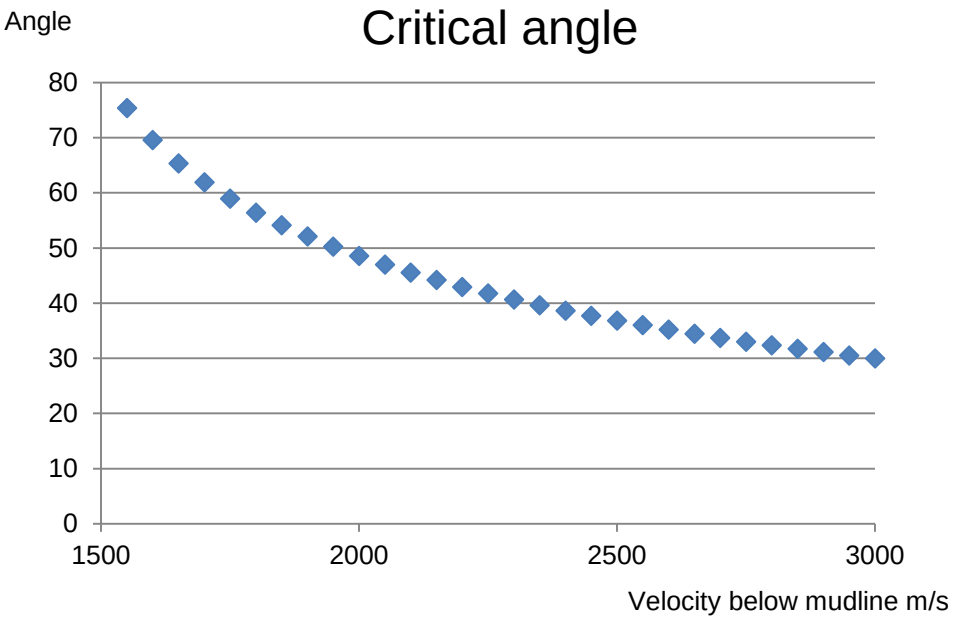


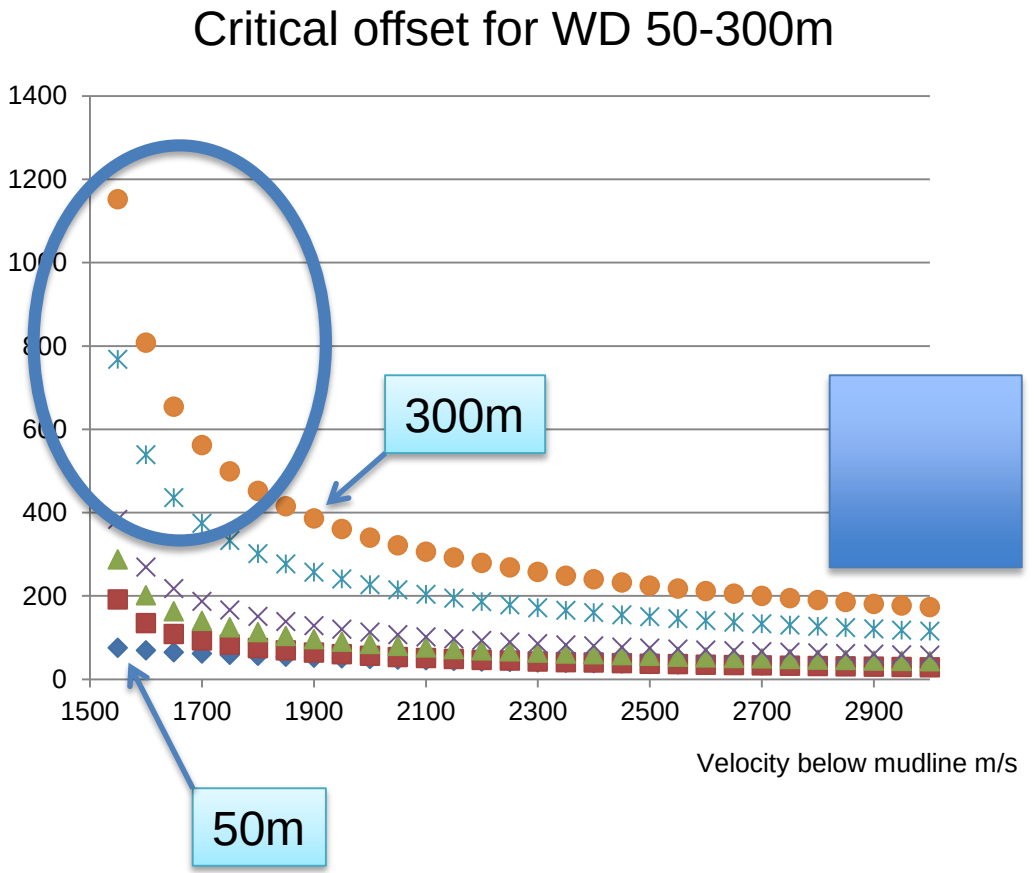
125m



500m

# Critical angle – Critical Offset



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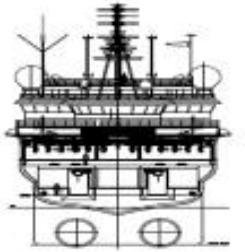
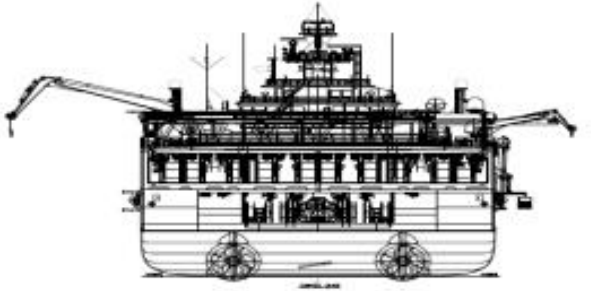
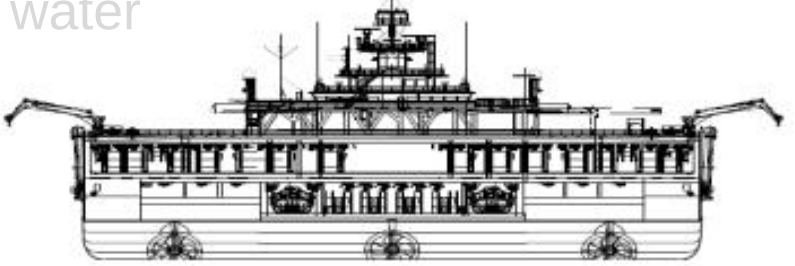


Conventional vessels

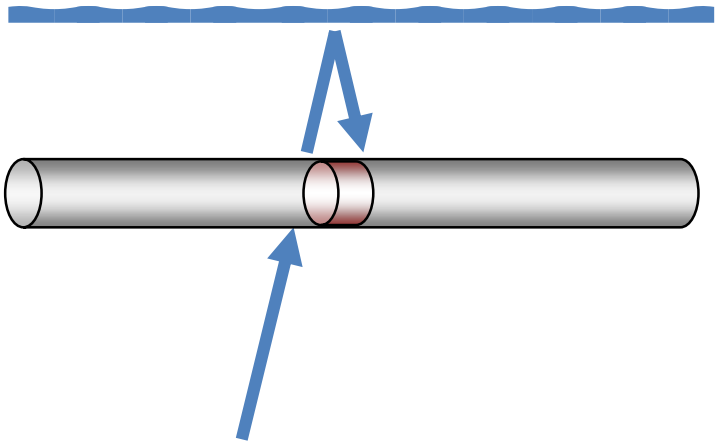


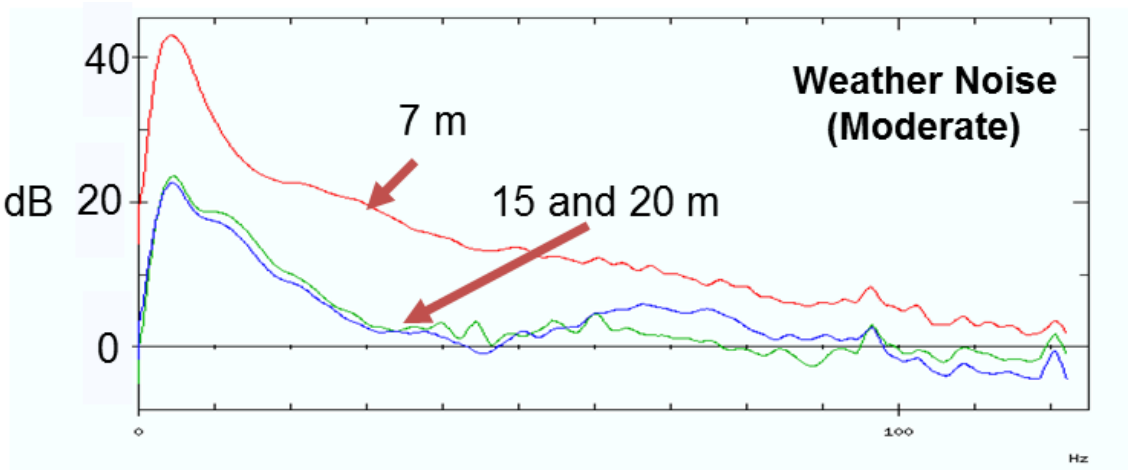
Ramform S-Class

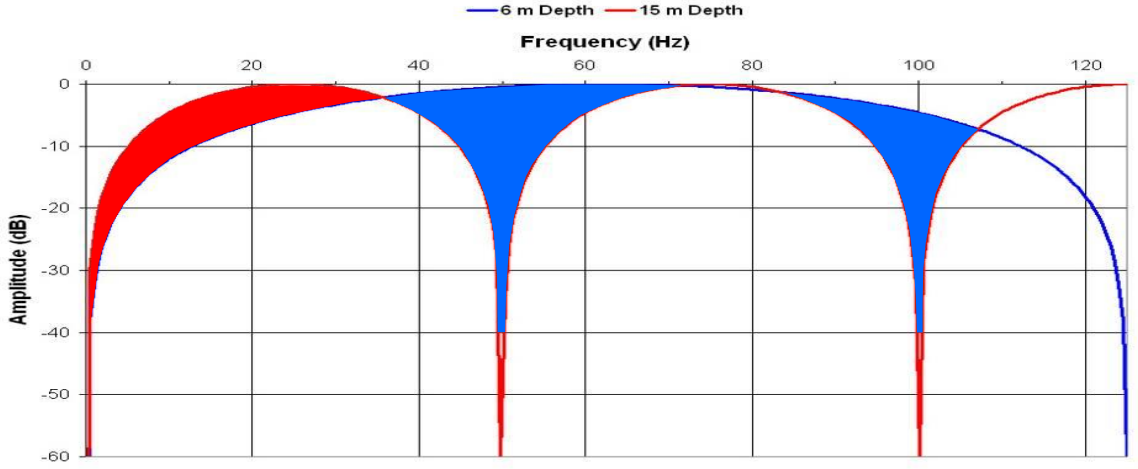


Ramform, Titan

# Towing deep: Benefits and Challenges – The Ghost



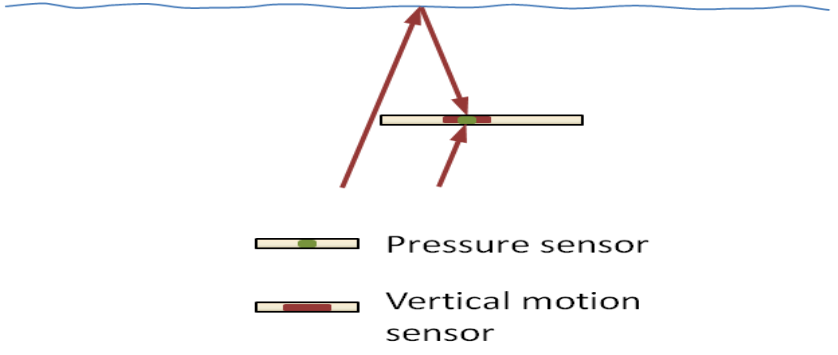


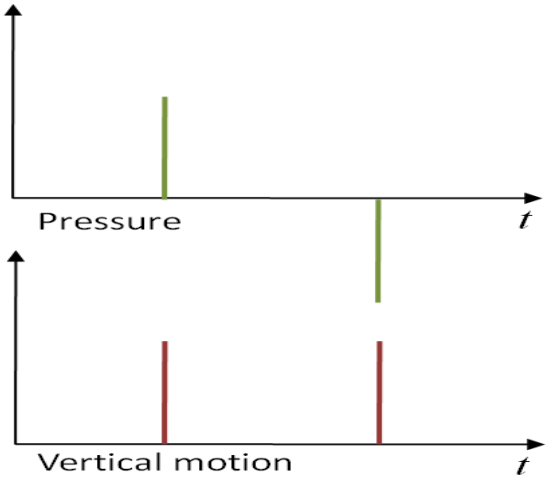

OBC theory and experience suggest that we could de-ghost streamer data with the additional information from a particle velocity measurement.

# Complementary ghost functions – receiver

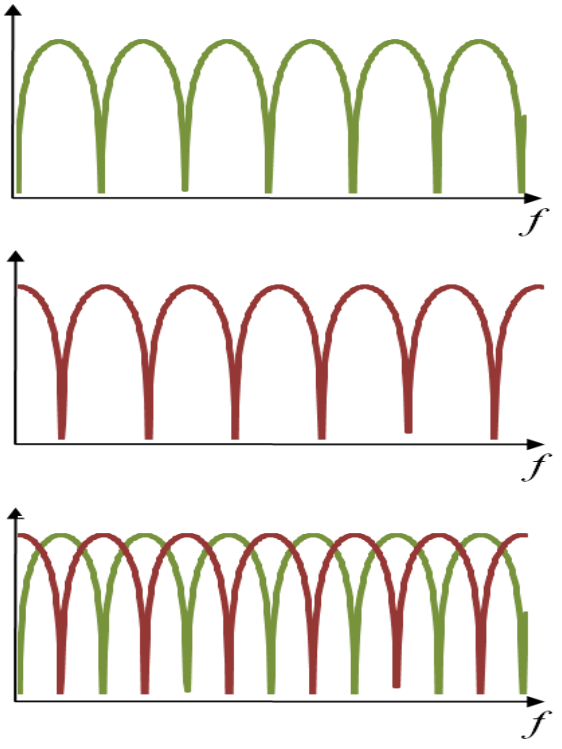
Colocated pressure and motion sensors




Their ghost functions




Spectra of the ghost functions

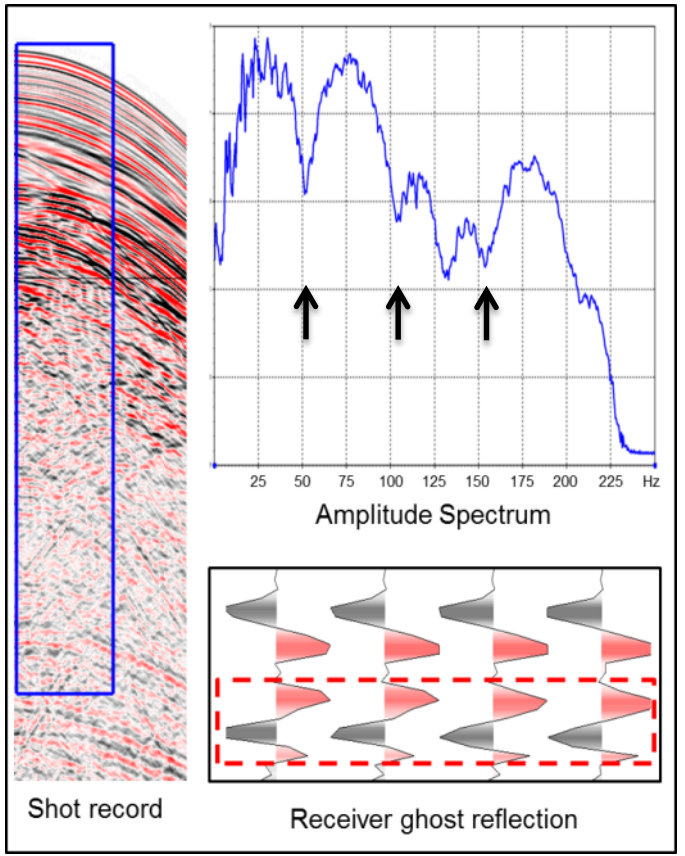



Full 2D and 3D

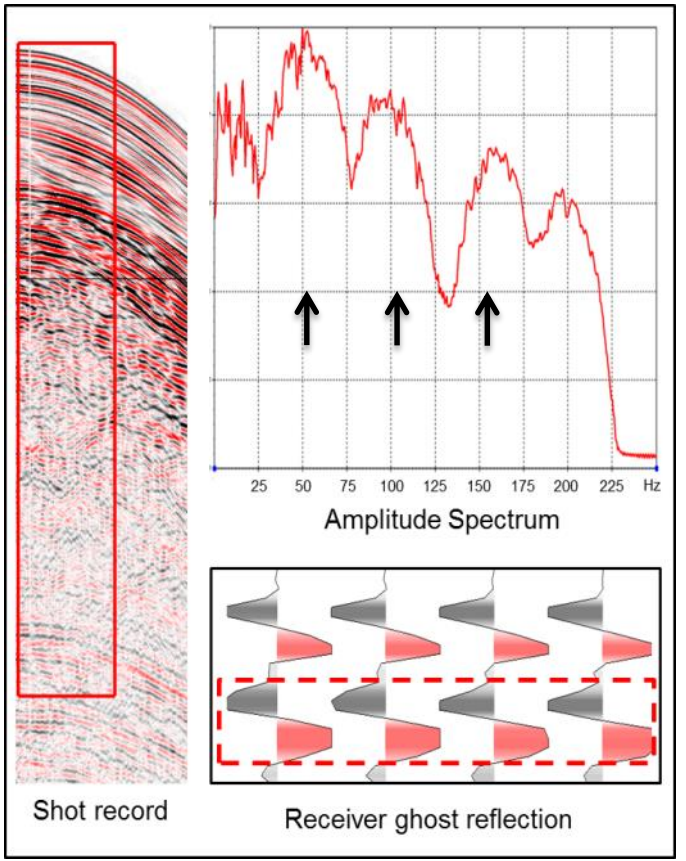
$$F(\omega, k_x, k_y) = \frac{\rho\omega}{k_z}, \quad \text{with} \quad k_z = \sqrt{\left(\frac{\omega}{v_w}\right)^2 - k_x^2 - k_y^2}$$

$$P^{up} = \frac{1}{2}(P - FV_z) \quad \text{and} \quad P^{down} = \frac{1}{2}(P + FV_z)$$

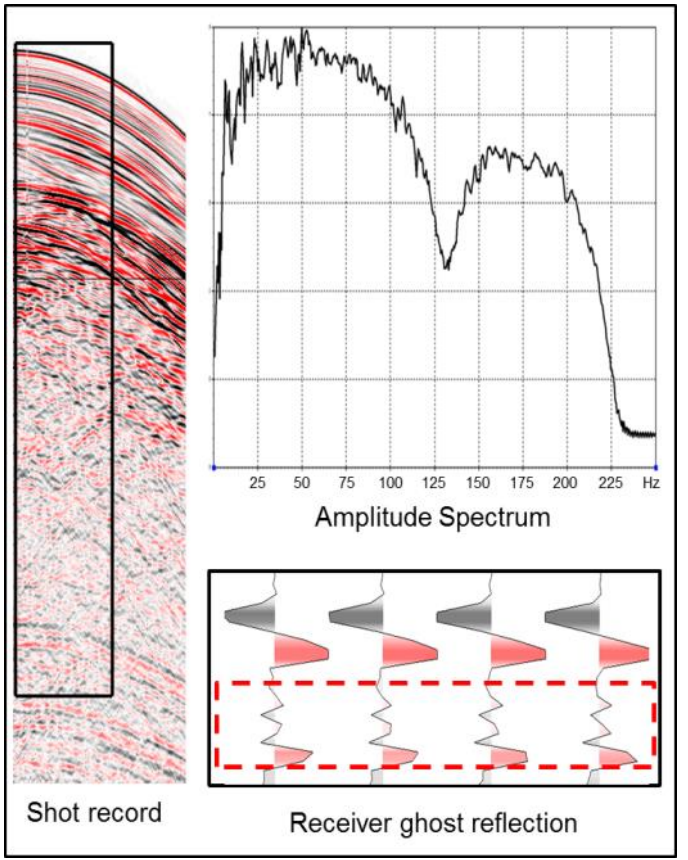
# Complementary Ghost Responses




Hydrophone



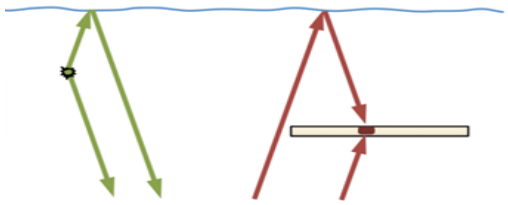

Velocity Sensor

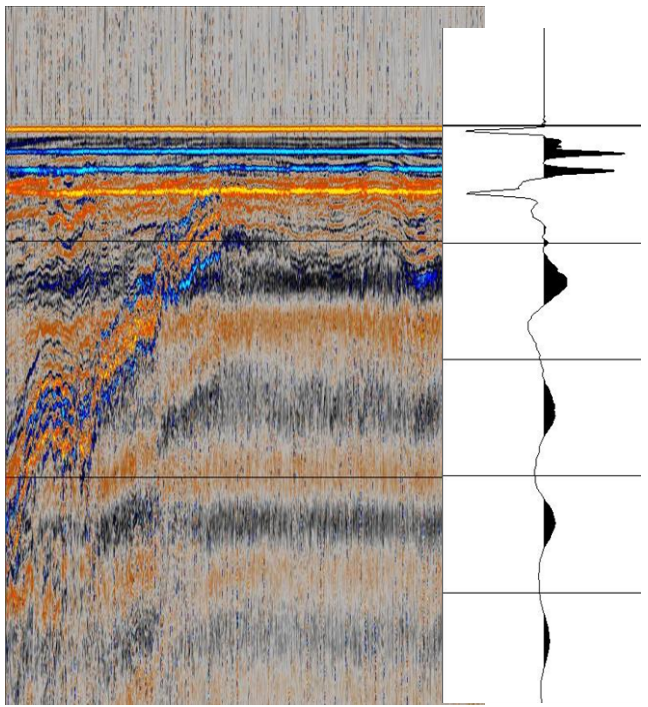



Receiver deghosted data

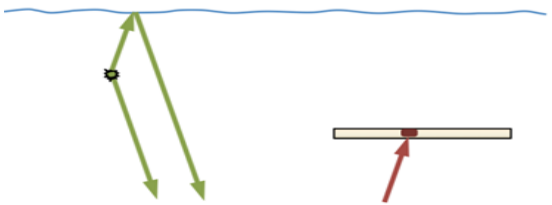
# Source and receiver deghosting

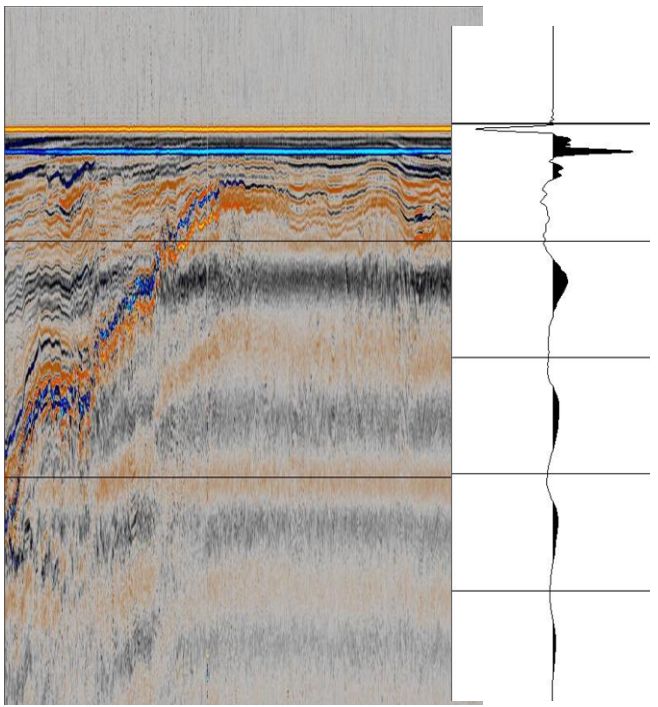
Both ghosts included



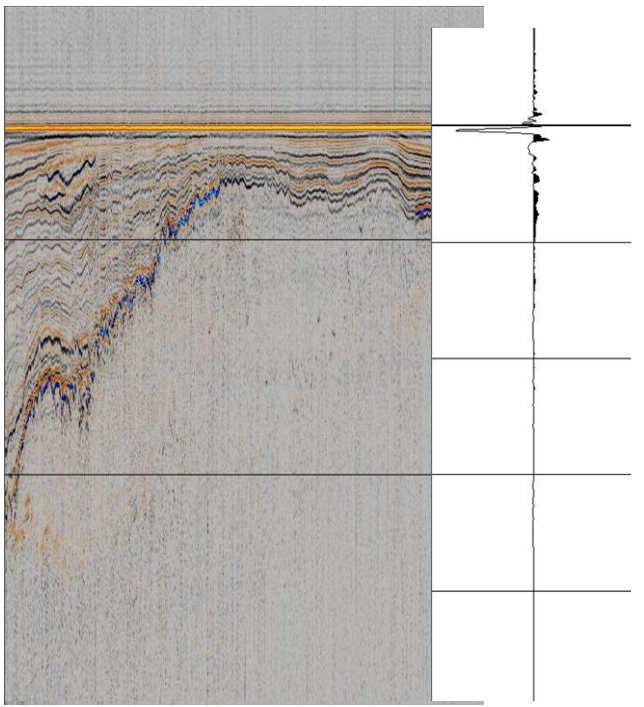


Receiver ghost removed





Both ghosts removed and de-signature



# Summary: GeoStreamer Wavefield Separation (= De-ghosting)

1. Method is very ***robust***, ***simple*** and ***accurate*** (adding of different sensor recordings)
2. Only ***measured*** information is used (no model required)
3. Only ***local*** sensor information is used (no borrowing from neighboring sensors)
4. Process is ***insensitive to sea-state*** and ***sensor depth*** variations
5. Unique access to ***wavefield estimates*** (P-UP and P-DWN)

# GeoStreamer benefits throughout the value chain

- Colocated pressure and velocity sensors
- Deep Tow

- Wave-field separation
  - Up and downgoing P and V

**Acquisition** → **Processing** → **Interpretation**

- Operational efficiency
- S/N
- Sea surface effects
- Seismic interference

- Velocities
- Multiple attenuation
- Q estimation
- Imaging

- 4D
- Inversion
- Reservoir Characterization

A Broader Bandwidth without restricting assumptions

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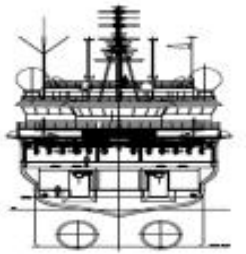

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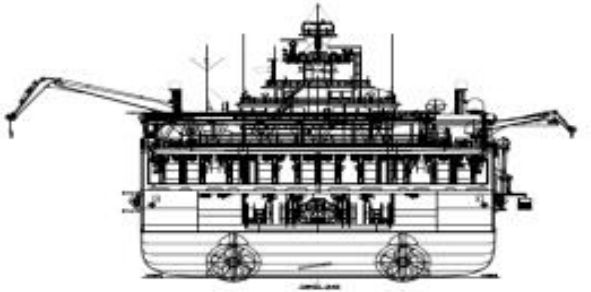

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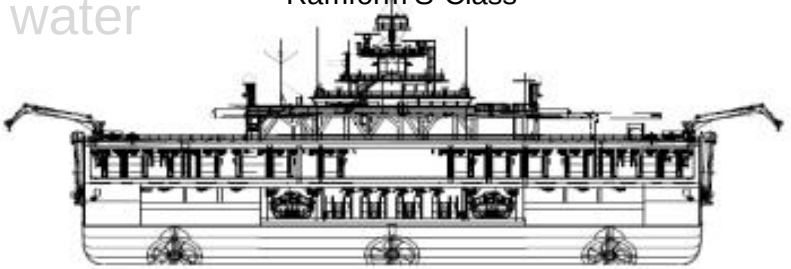
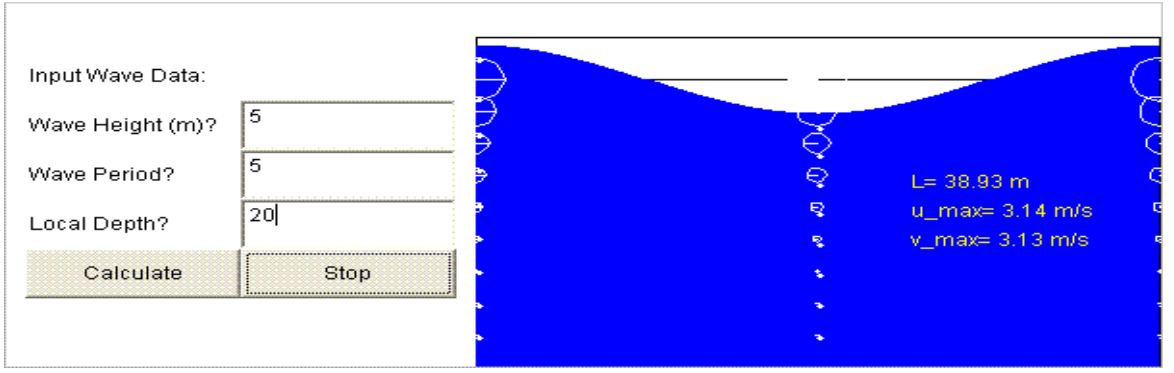


Ramform, Titan

# Wve motion decreases exponentially away from the sea surface

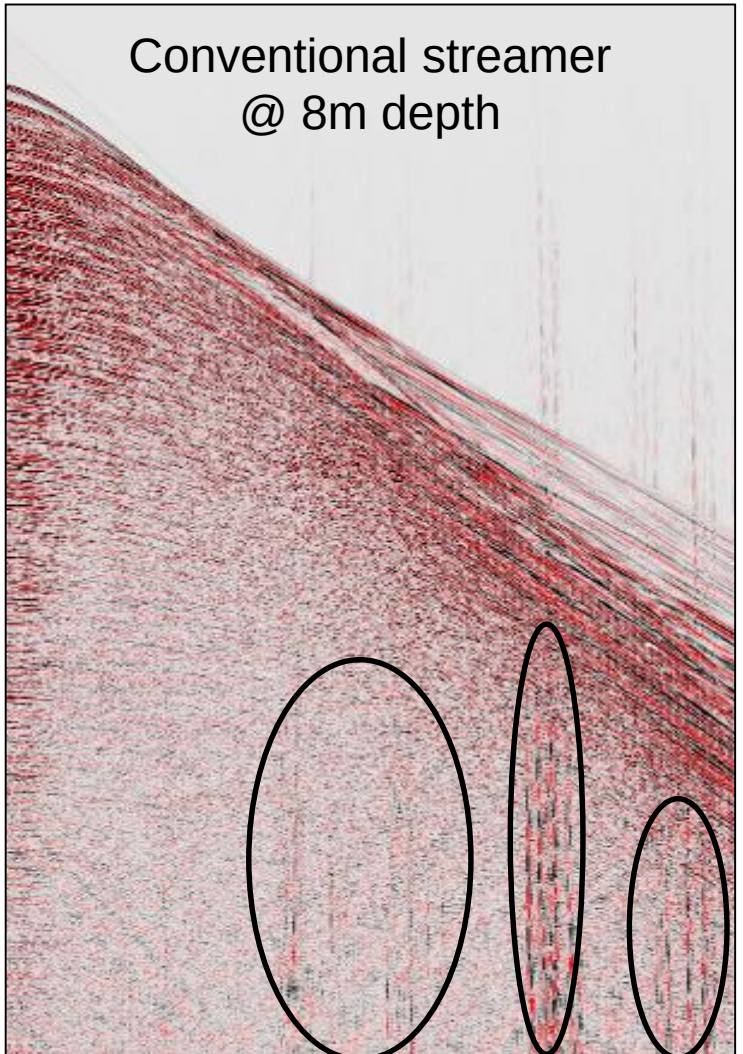


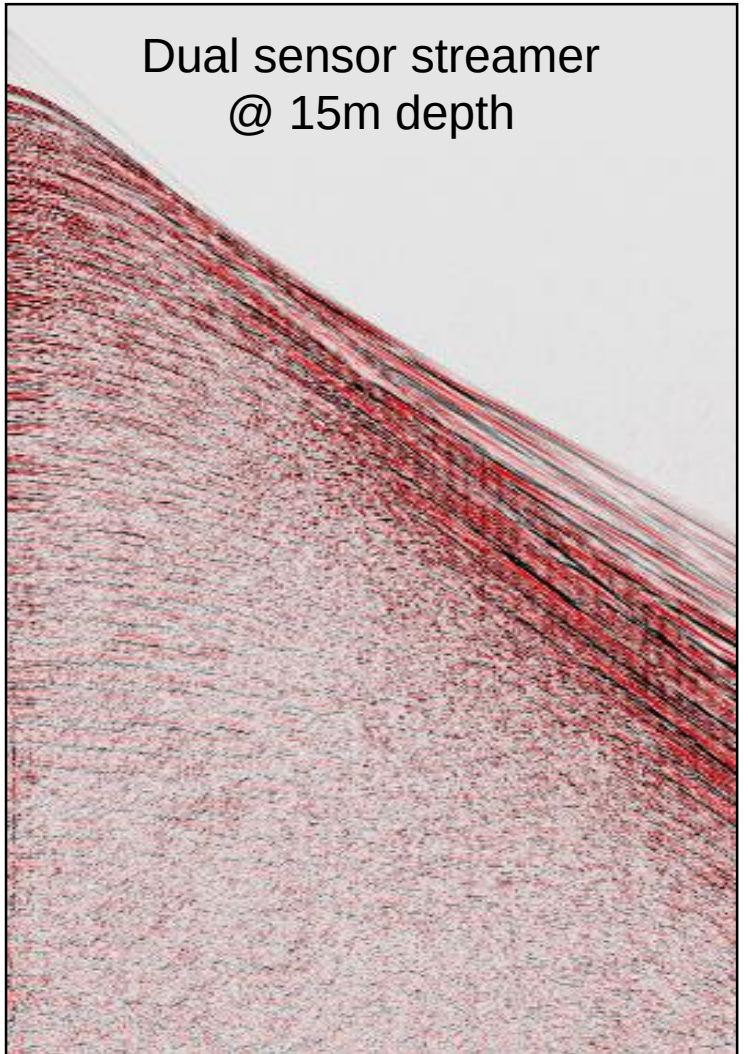

The above movie shows the wave form of a “perfect” surface wave in water. It also shows the associated water particle position as a dot and the velocity vector as a line.

L is the wavelength
u_max is the horizontal velocity
v_max is the vertical velocity

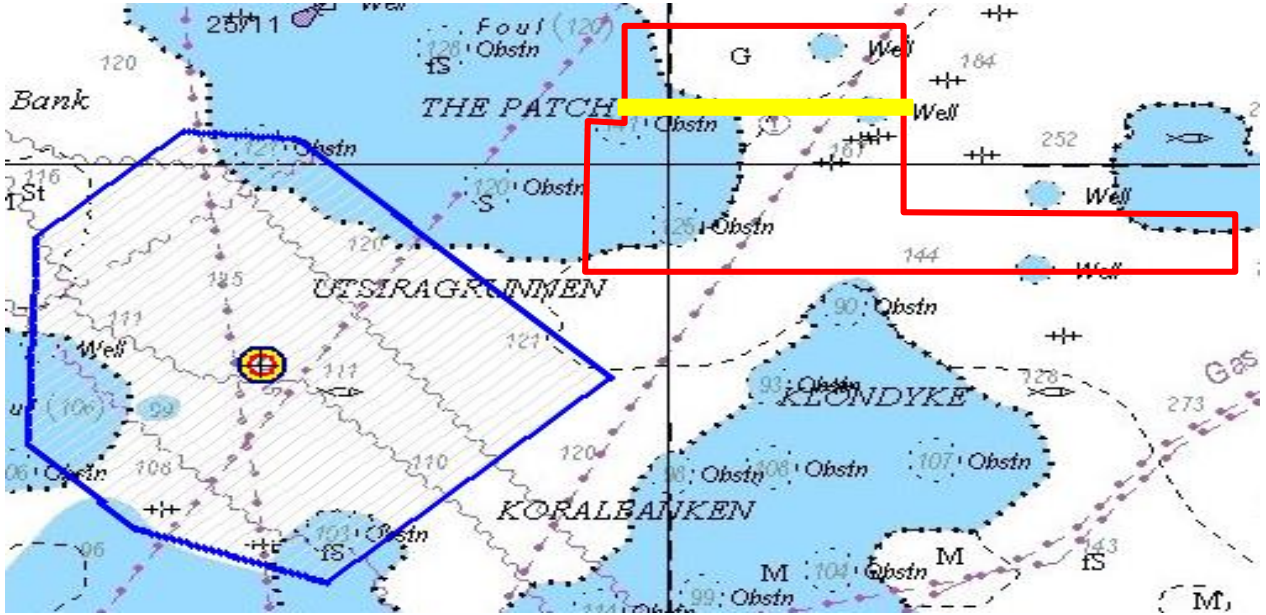
(From Robert A. Dalrymple, Center for Applied Coastal Research, Univ. of Delaware)

# Weather Related Noise – North Sea



# North Sea - GeoStreamer vs Conventional




| (15th April – 19th June) | | |
|---|---|---|
| **Vessel** | Ocean Explorer | Atlantic Explorer |
| **Streamer type** | Conventional | **GeoStreamer (dual sensor)** |
| **Towing Depth** | 8m | **15m** |
| **Weather standby** | **405hrs (24%)** | **62hrs (4%)** |

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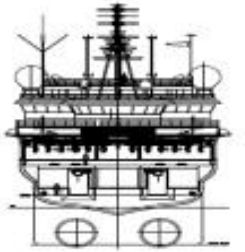

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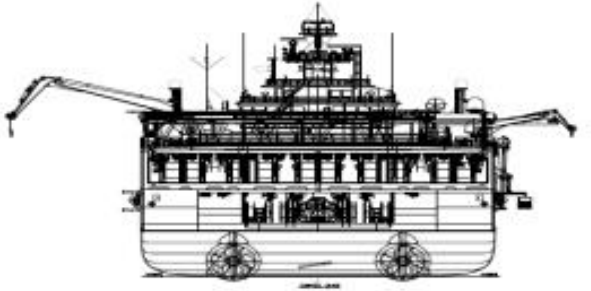

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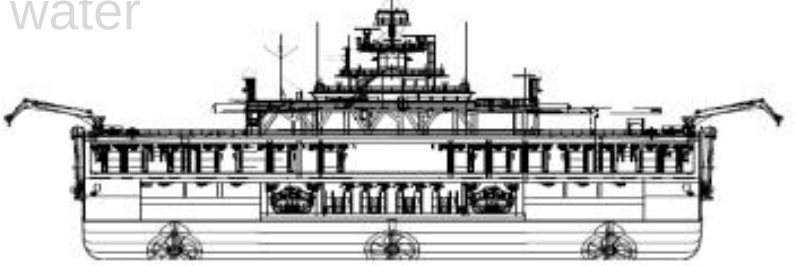
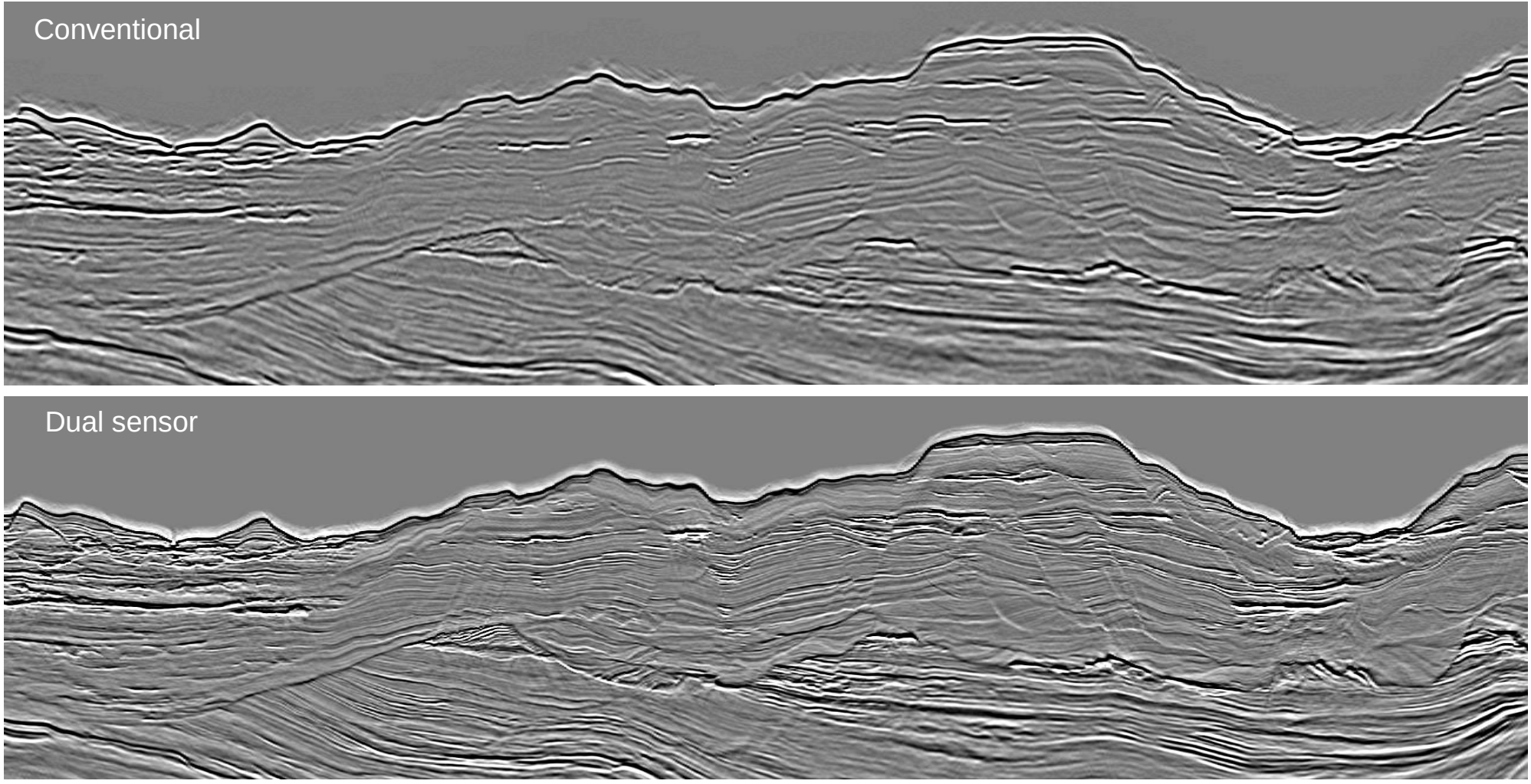
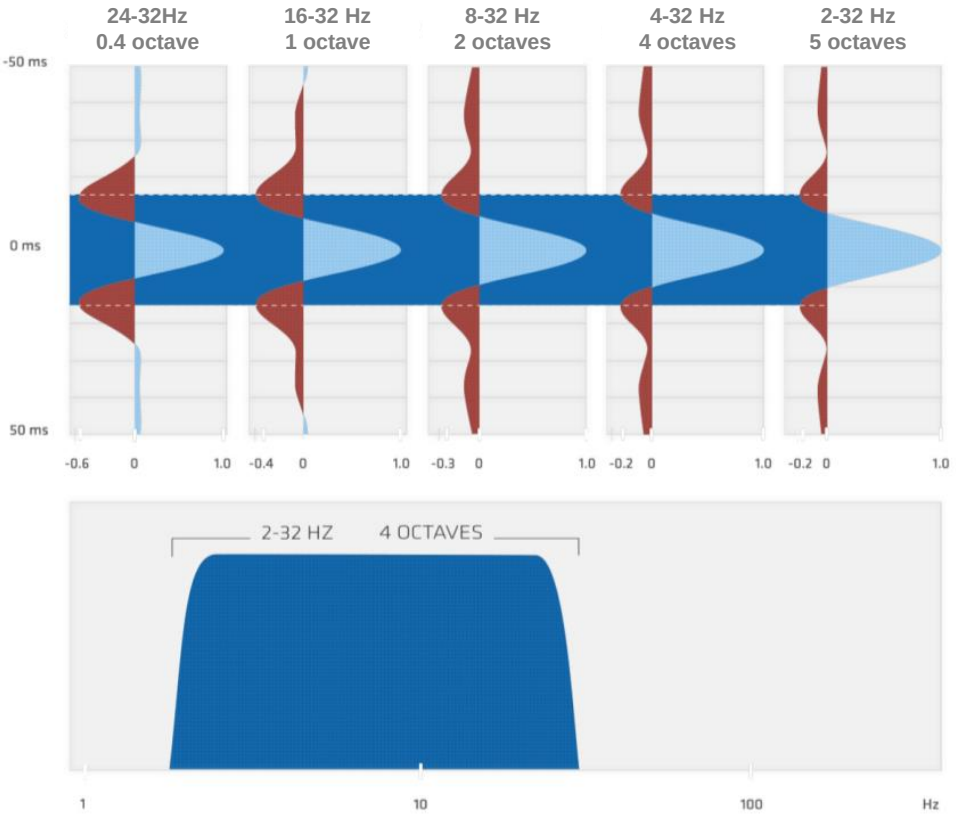


Ramform, Titan

# Camamu Area - Brazil



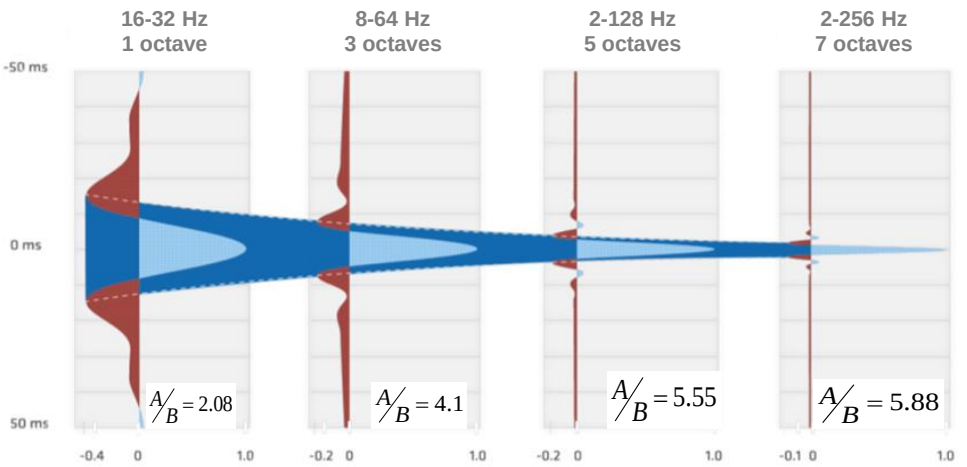
# Narrow bandwidth *vs* Broadband seismic – wavelet characteristic?

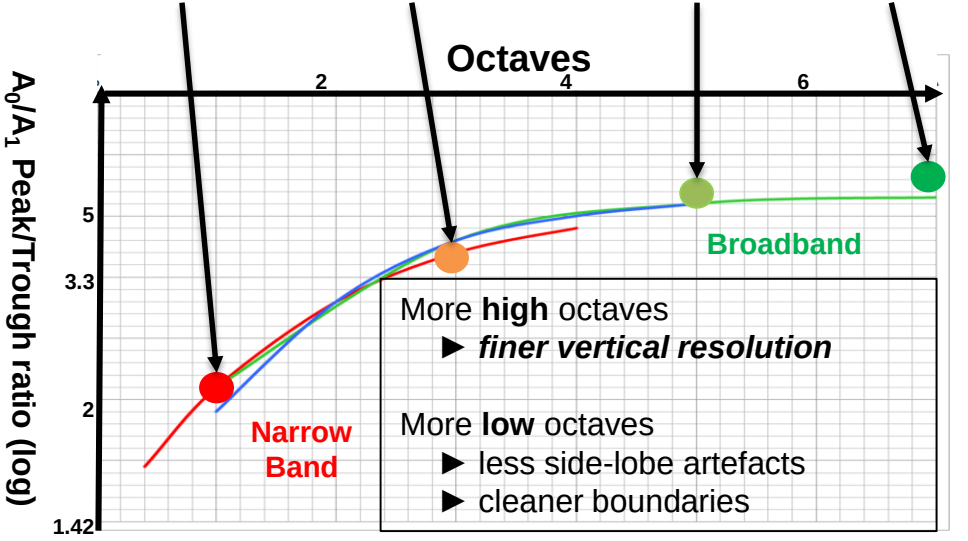



**Low Frequency extension**

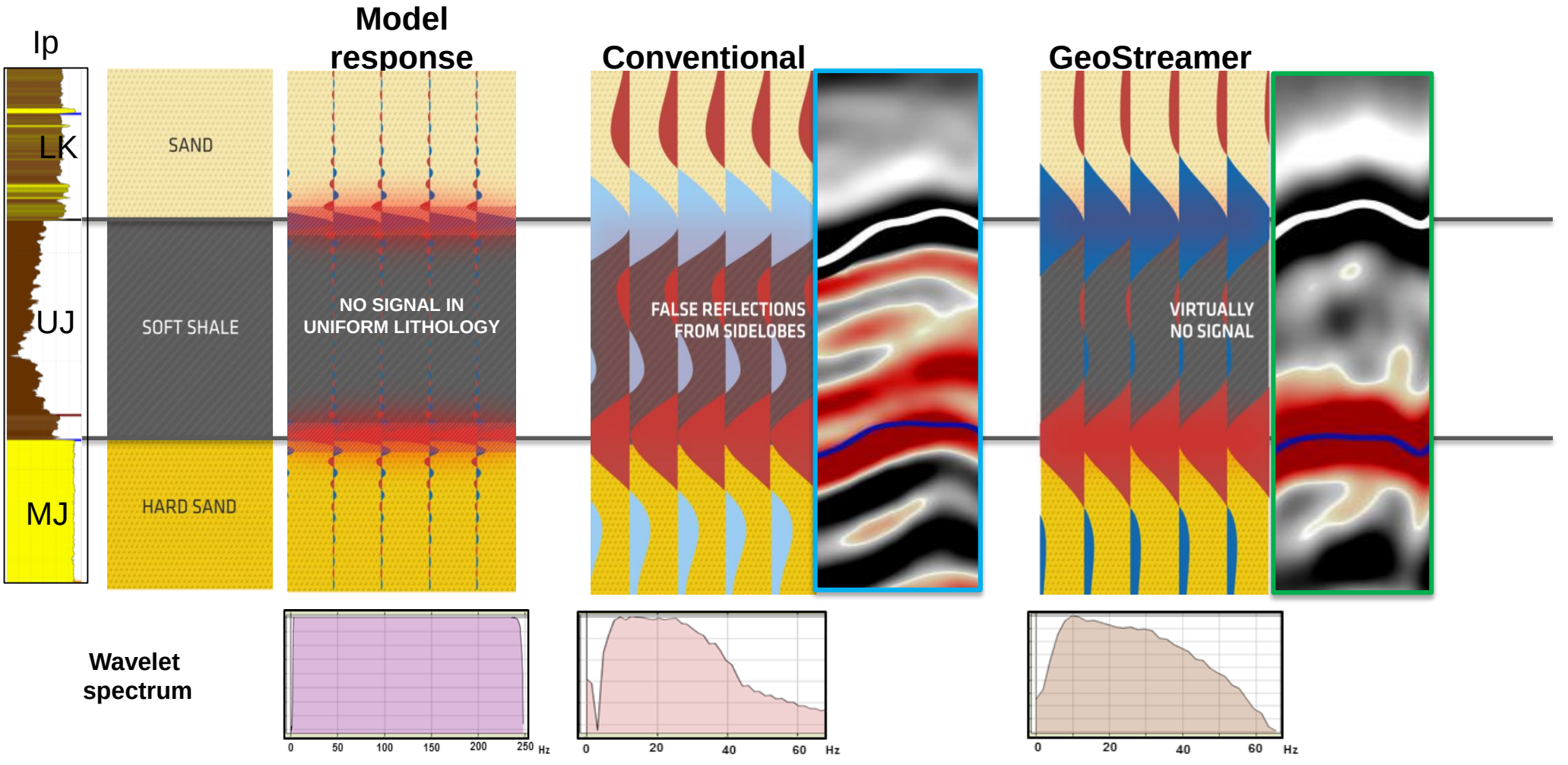
Reduced side-lobes

➢ Less artefacts

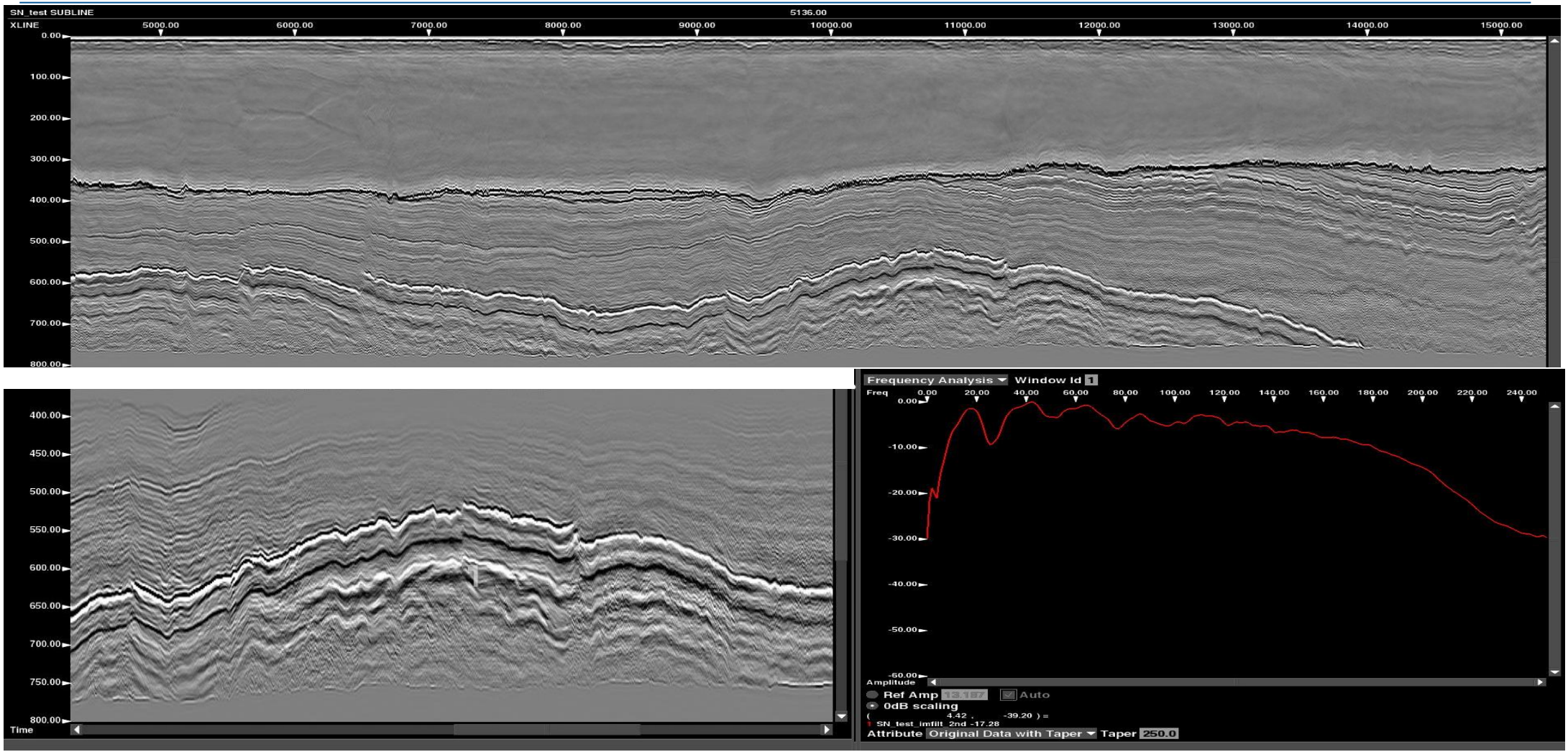


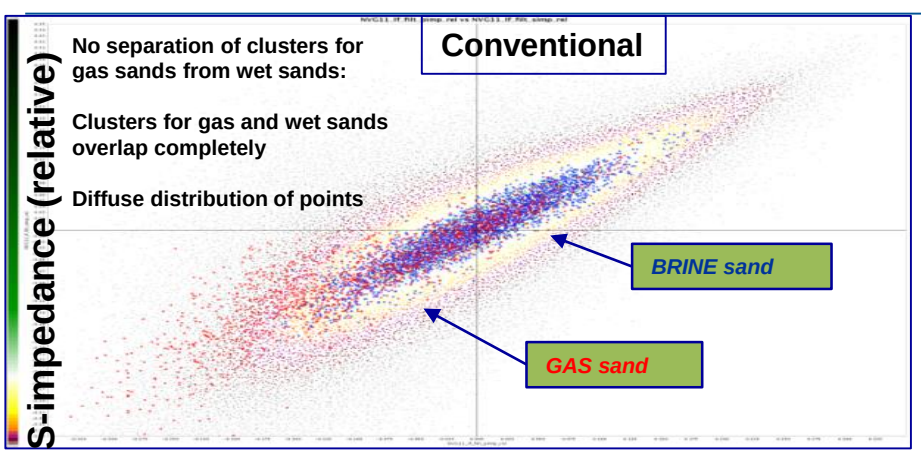
# 1D Modelling Schematic – the fundamentals

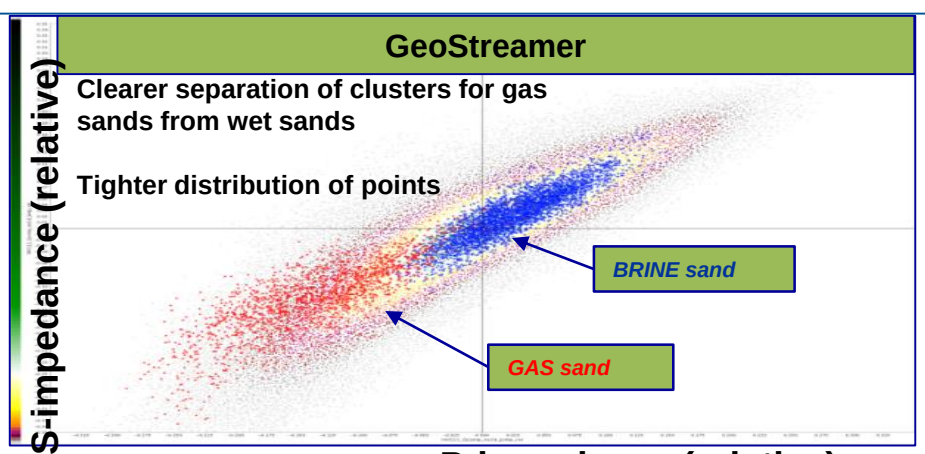


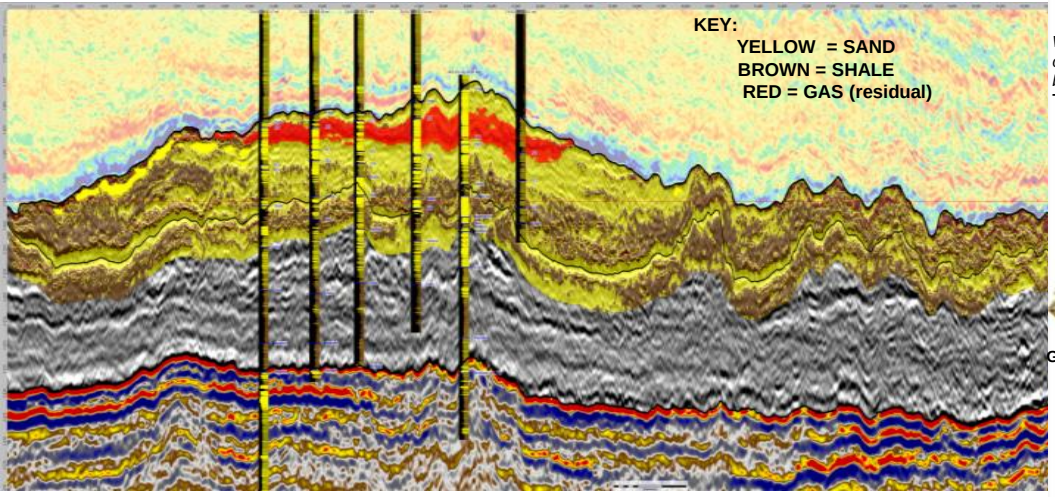
# Barents Sea – High Res

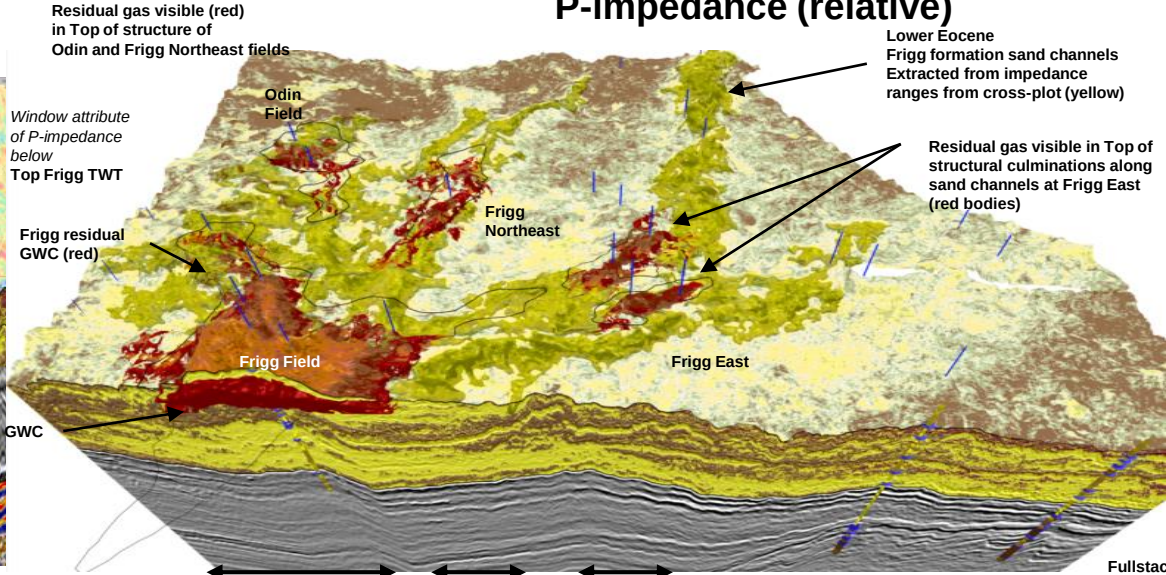


# **Frigg field area, NVG:** GeoStreamer seismic bandwidth enables better lithology discrimination and fluid prediction



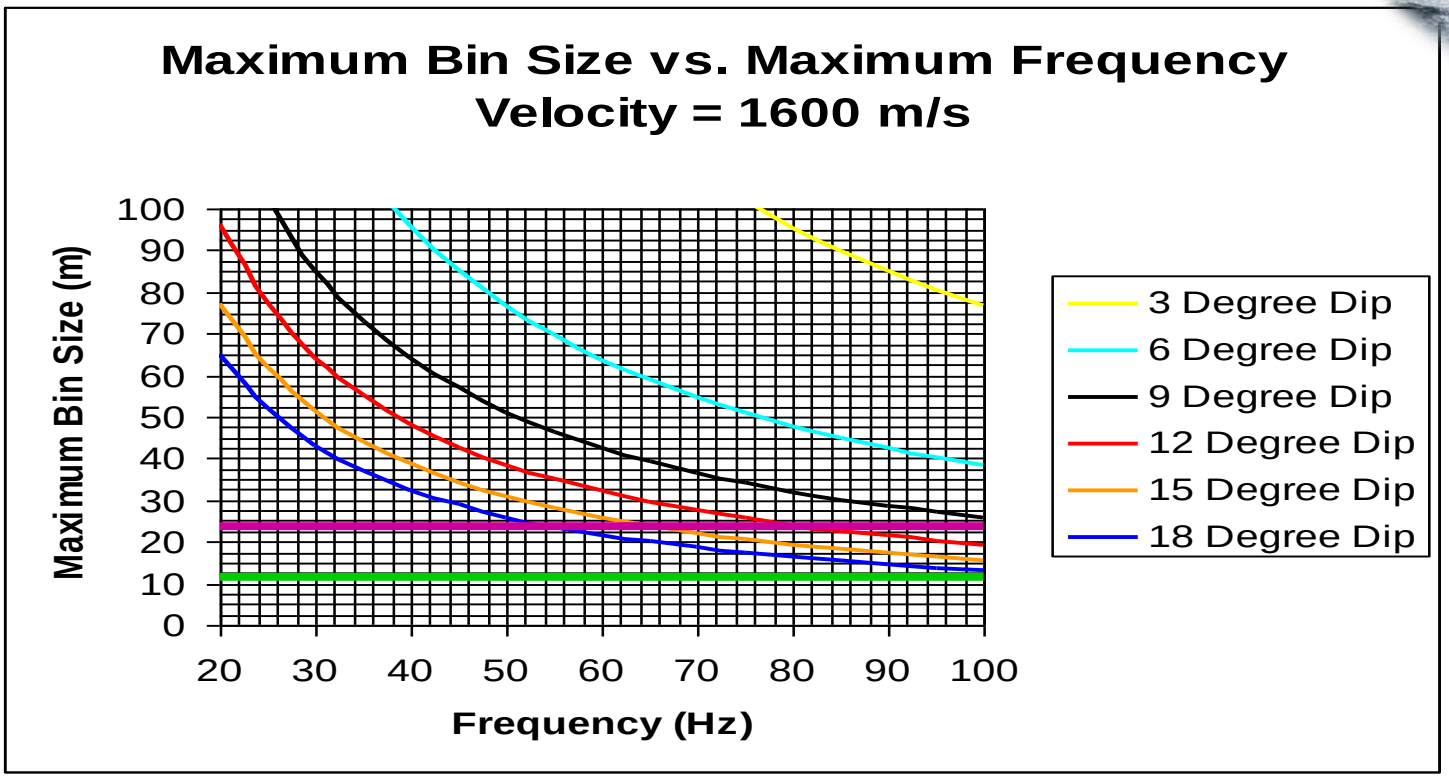



# Spatial Sampling

**Let's not forget the spatial version of Nyquist in in this Broadband Age**




Towing Capability is Key to achieving the right sampling at the right cost.

# High Res Acquisition

| Acquisition Parameters | Dual Source | High Density Dual Source | Triple Source | High Density Triple Source | P-Cable Single Source | High Density Triple Source |
|---|---|---|---|---|---|---|
| Streamer Spread | 12x75m | 18x50m | 12x75m | 18x50m | 16x12.5m | 16x37.5m |
| Crossline Bin Size | 18.75m | 12.5m | 12.5m | 8.33m | 6.25m | 6.25m |
| Sail Line Separation | 450m | 450m | 450m | 450m | 100m | 300m |

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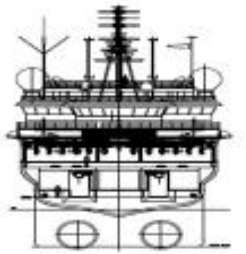
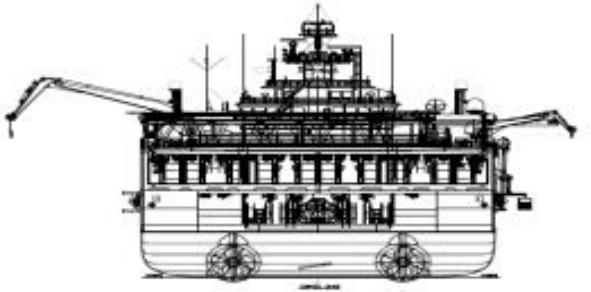
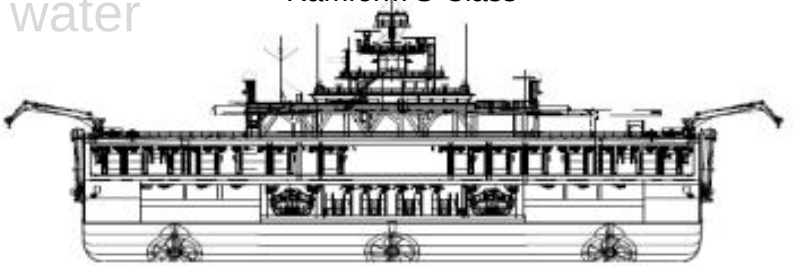


Conventional vessels

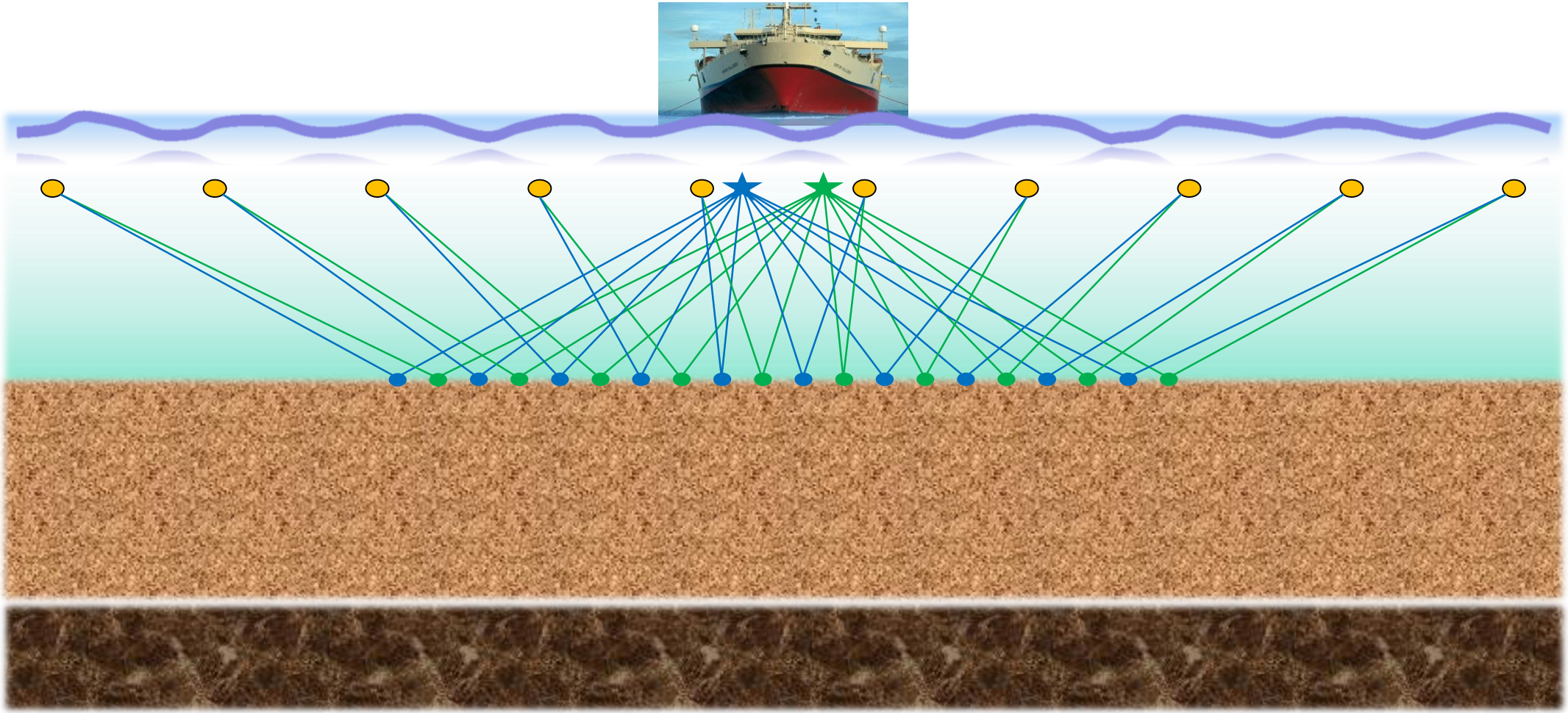


Ramform S-Class

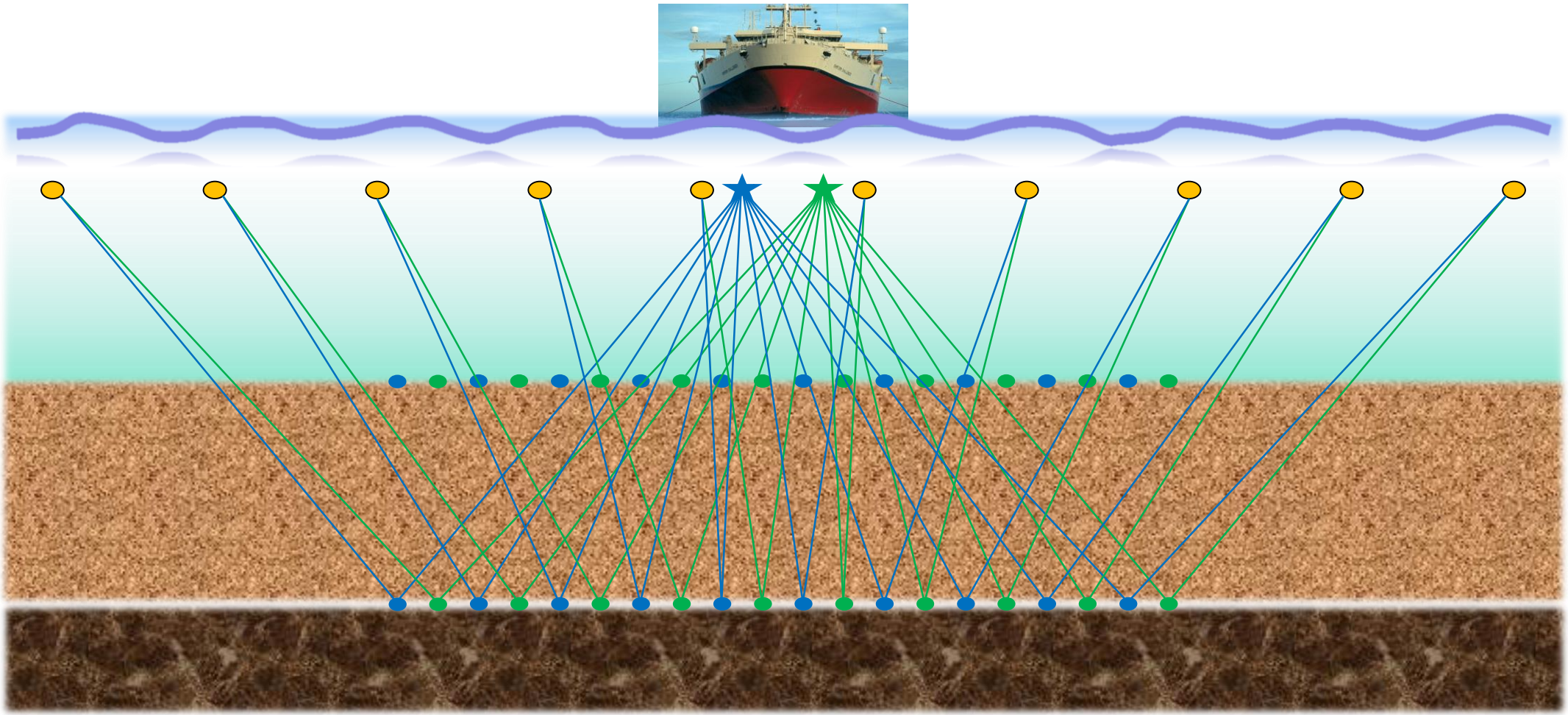


Ramform, Titan

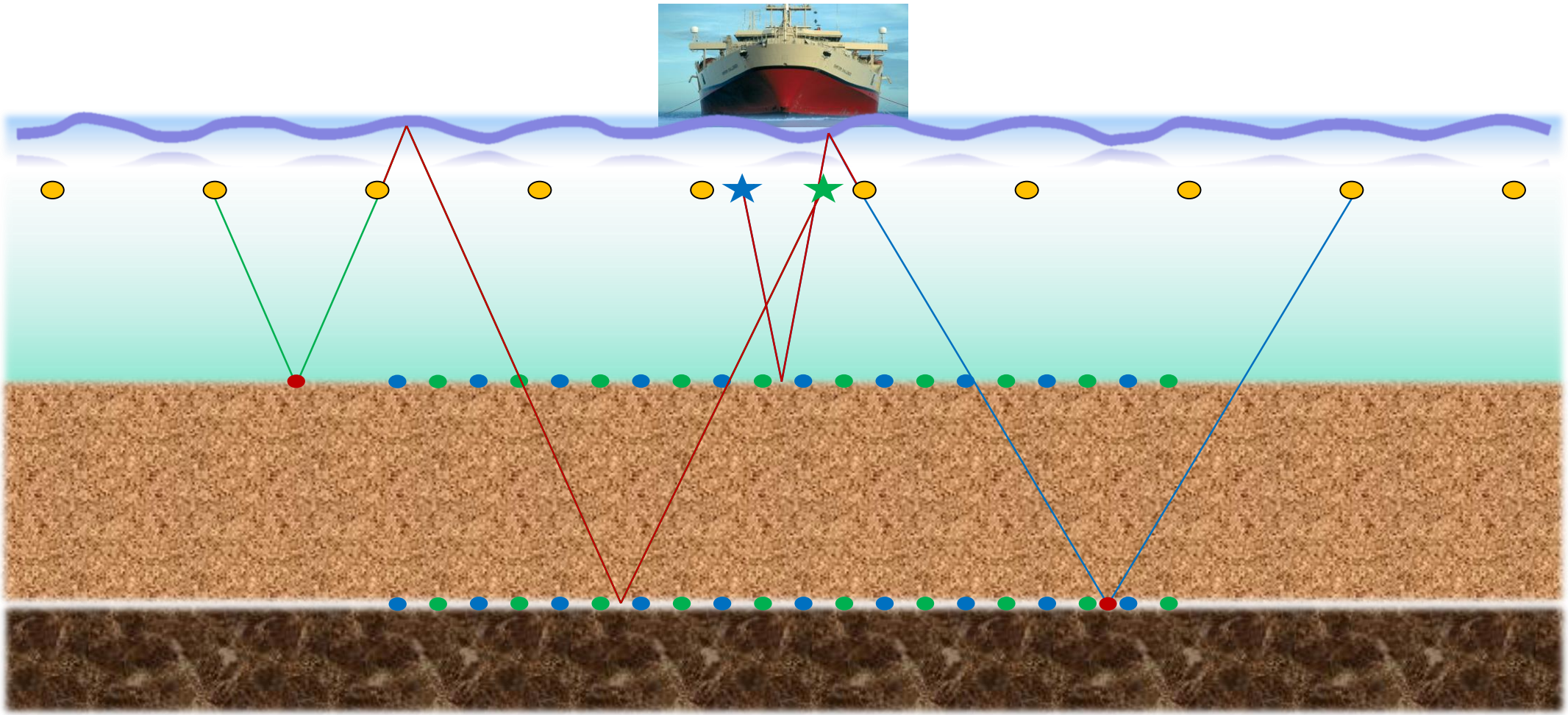
# Imaging the Seabed



# Imaging the subsurface

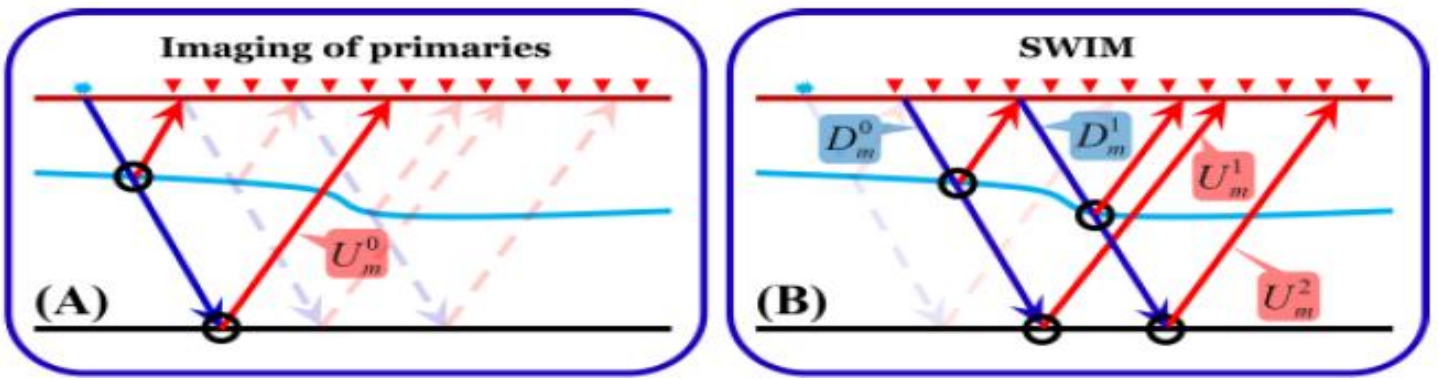


# We normally throw away ray-paths like these



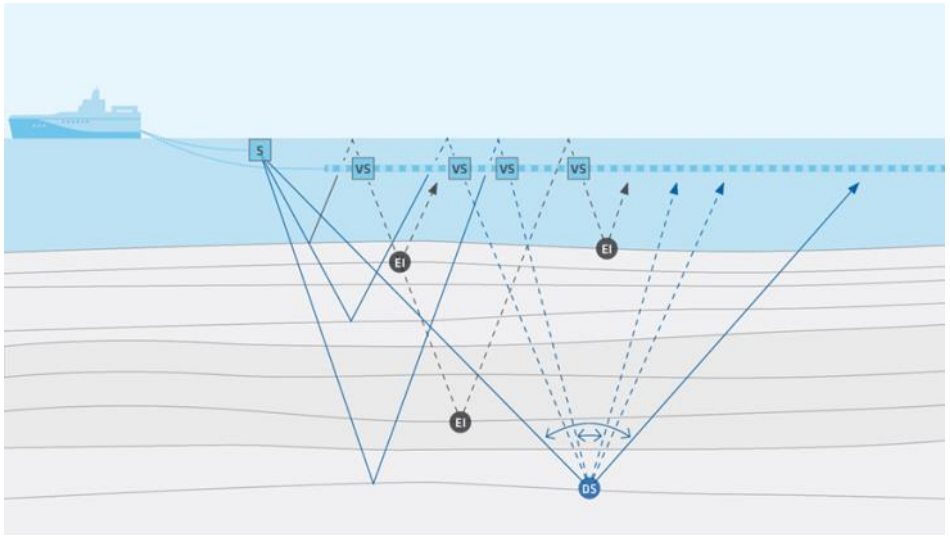
# Principles of SWIM

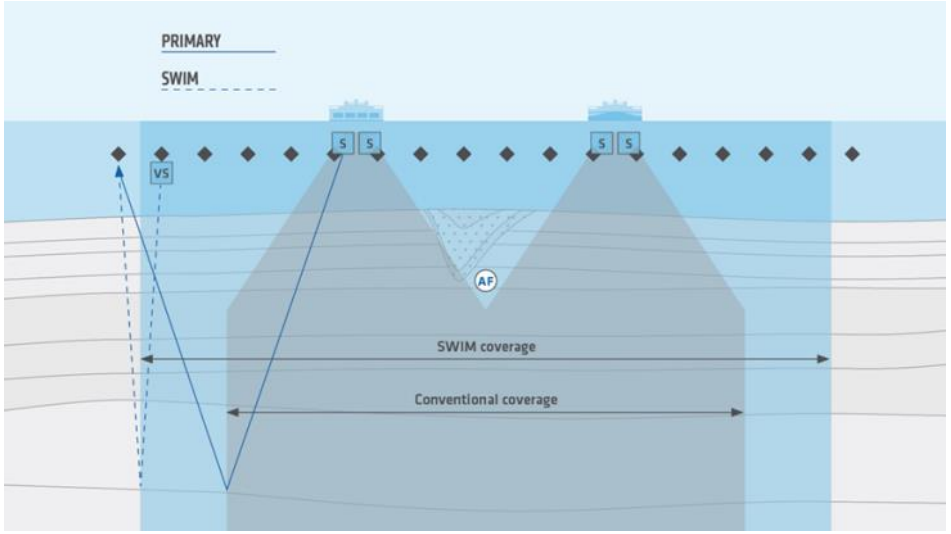
- SWIM (Separated Wavefield Imaging) utilises the up- and down-going wavefields and free-surface related multiples in order to provide improved imaging of the subsurface in shallow water areas. This method can provide superior illumination and angular diversity compared to imaging techniques which use primary energy.




Whitmore, N.D., Valenciano, A.A, Sollner W. and Lu, S. 2010. Imaging of primaries and multiples using a dual-sensor towed streamer. 80th Annual International Meeting, SEG, Expanded Abstract.

# Separated wavefield imaging – two important implications

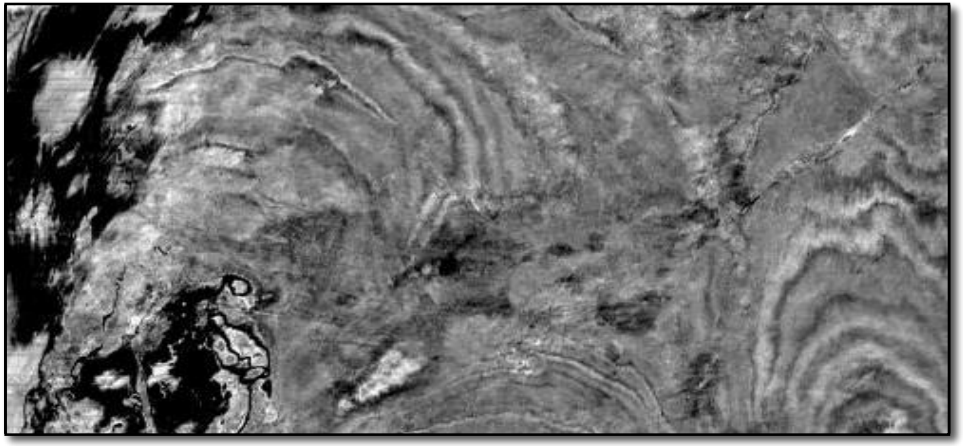



By separating the wavefields each receiver can be treated as a new ‘virtual source’ (VS).

Sub-surface illumination (EI) is extended by using the wavefield separated data as a new VS.

Angular diversity (DS) is improved by increasing the density of source points.



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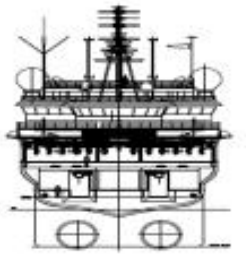
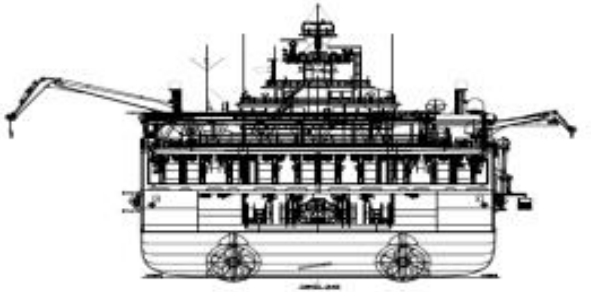
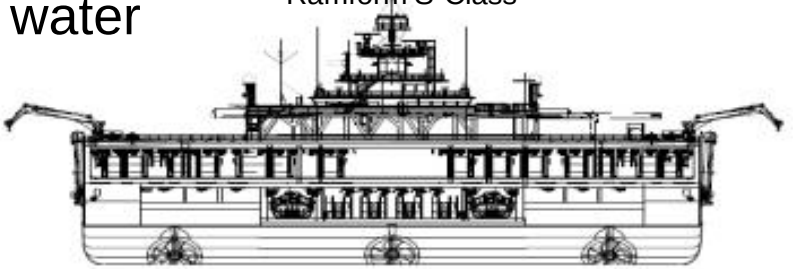


Conventional vessels

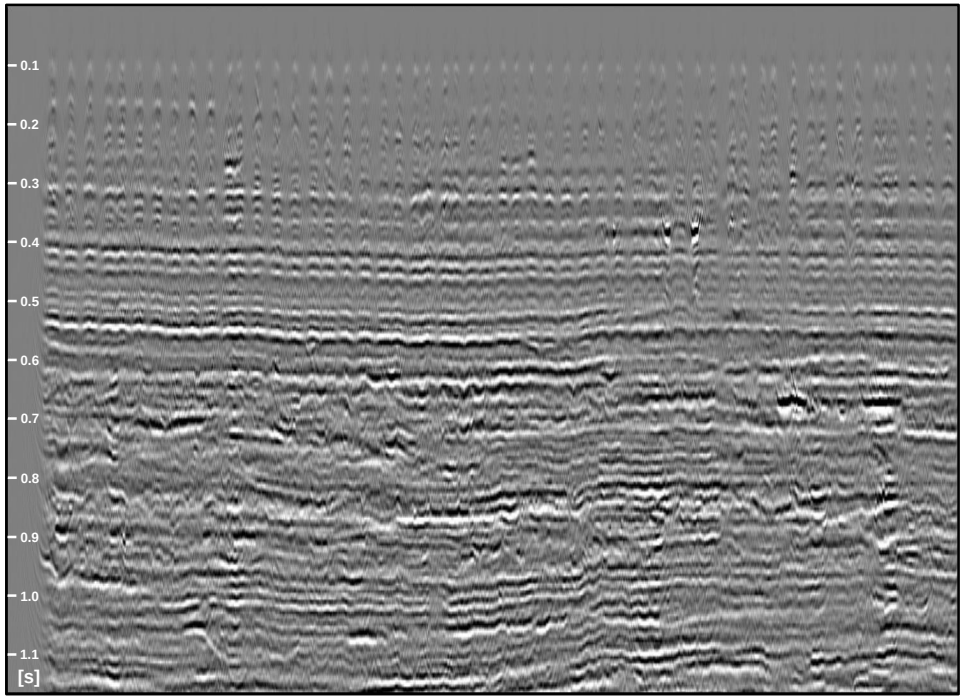


Ramform S-Class

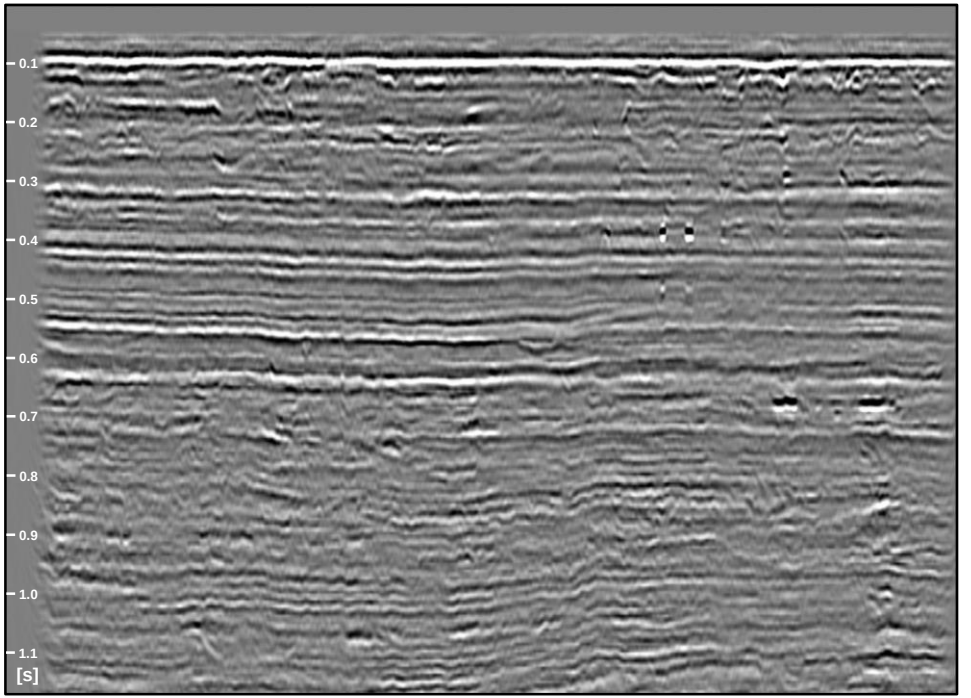


Ramform, Titan

# SWIM illumination overburden Image Malaysia



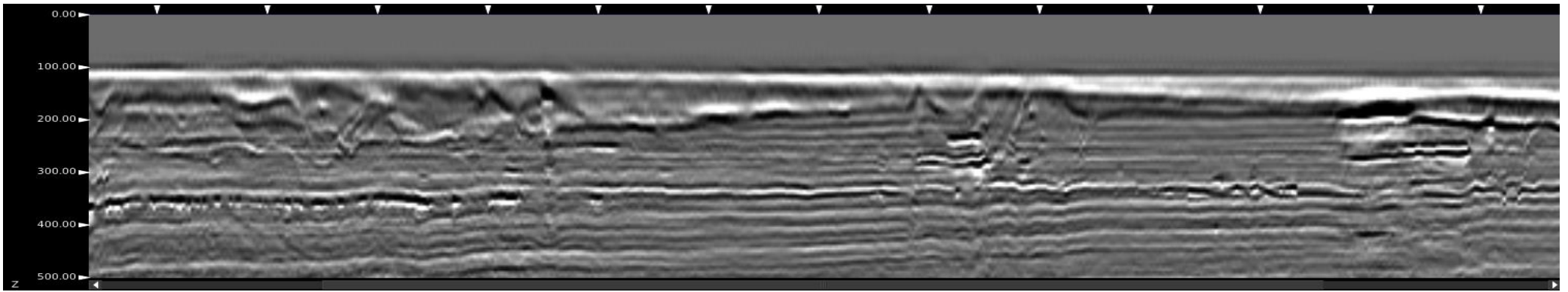

CONVENTIONAL IMAGING

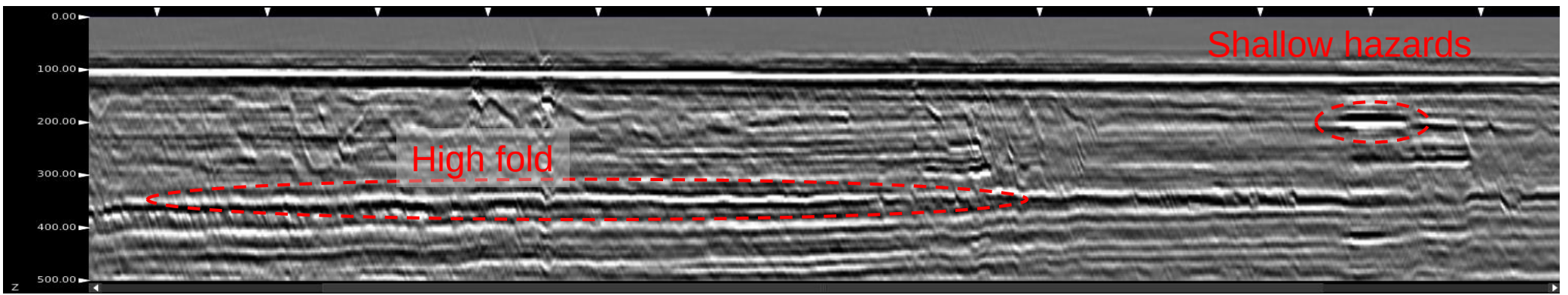



SWIM

# Edward Grieg : SWIM vs Kirchhoff PSDM

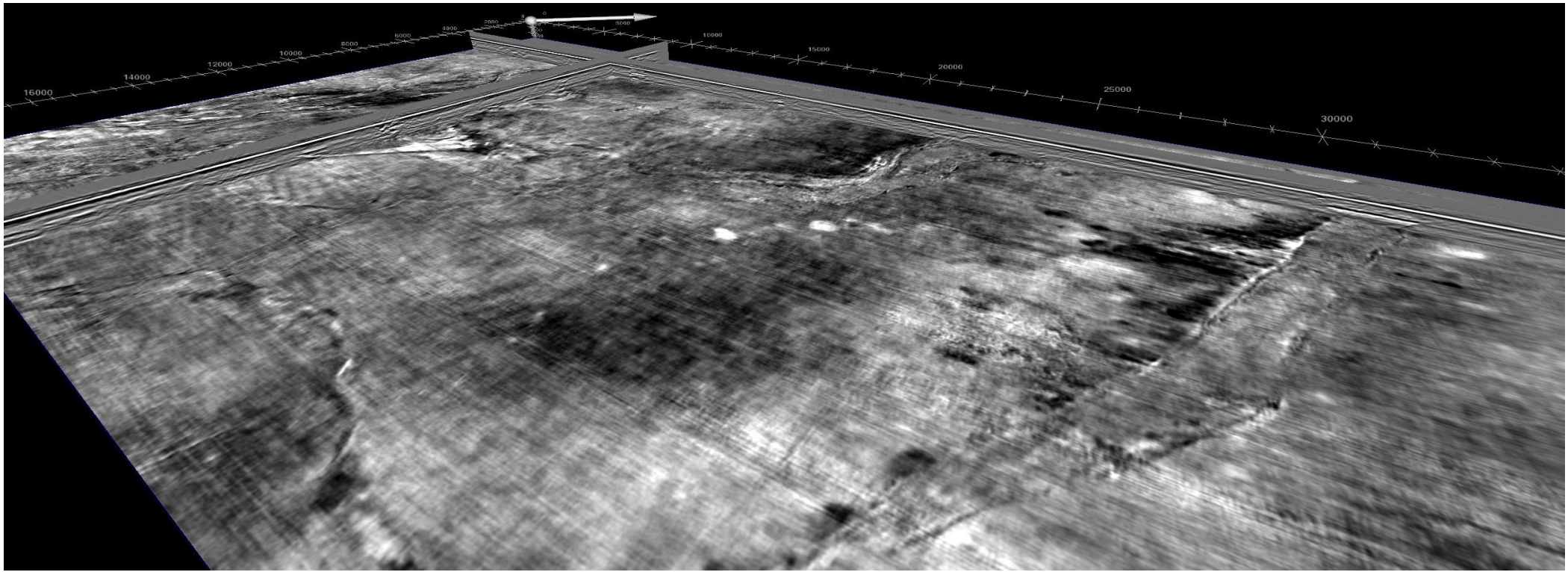
Kirchhoff PSDM stack



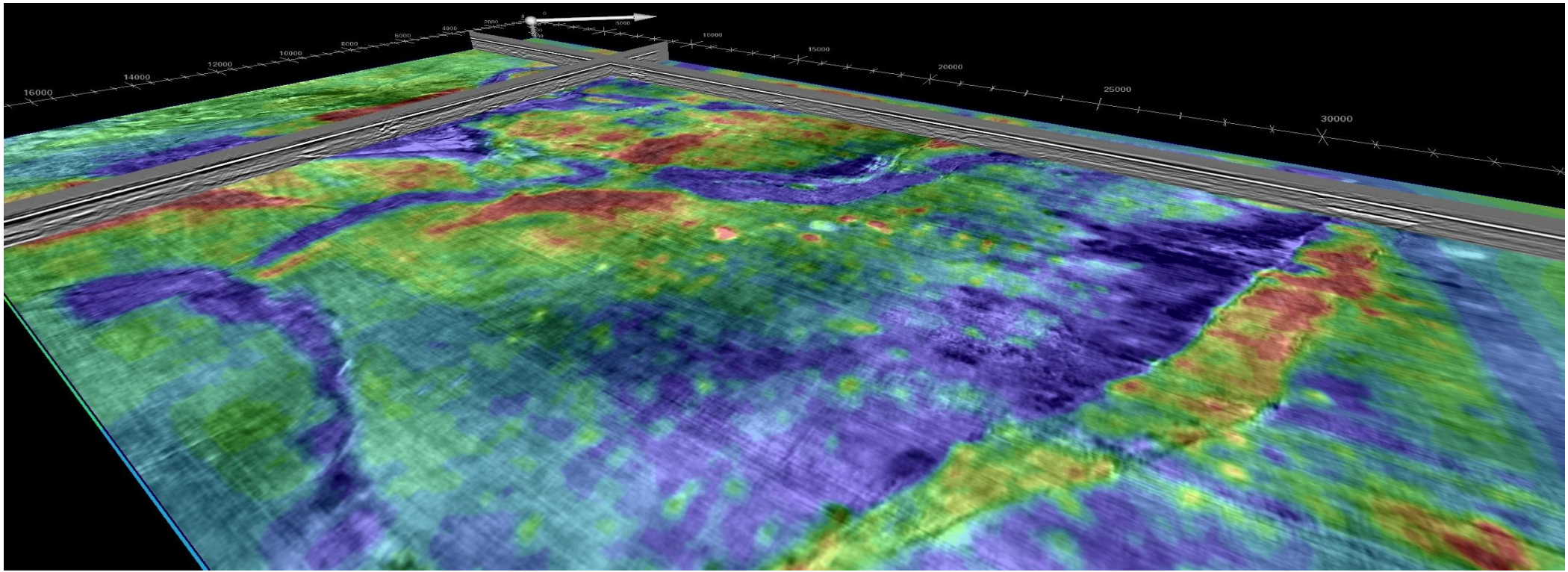




SWIM stack

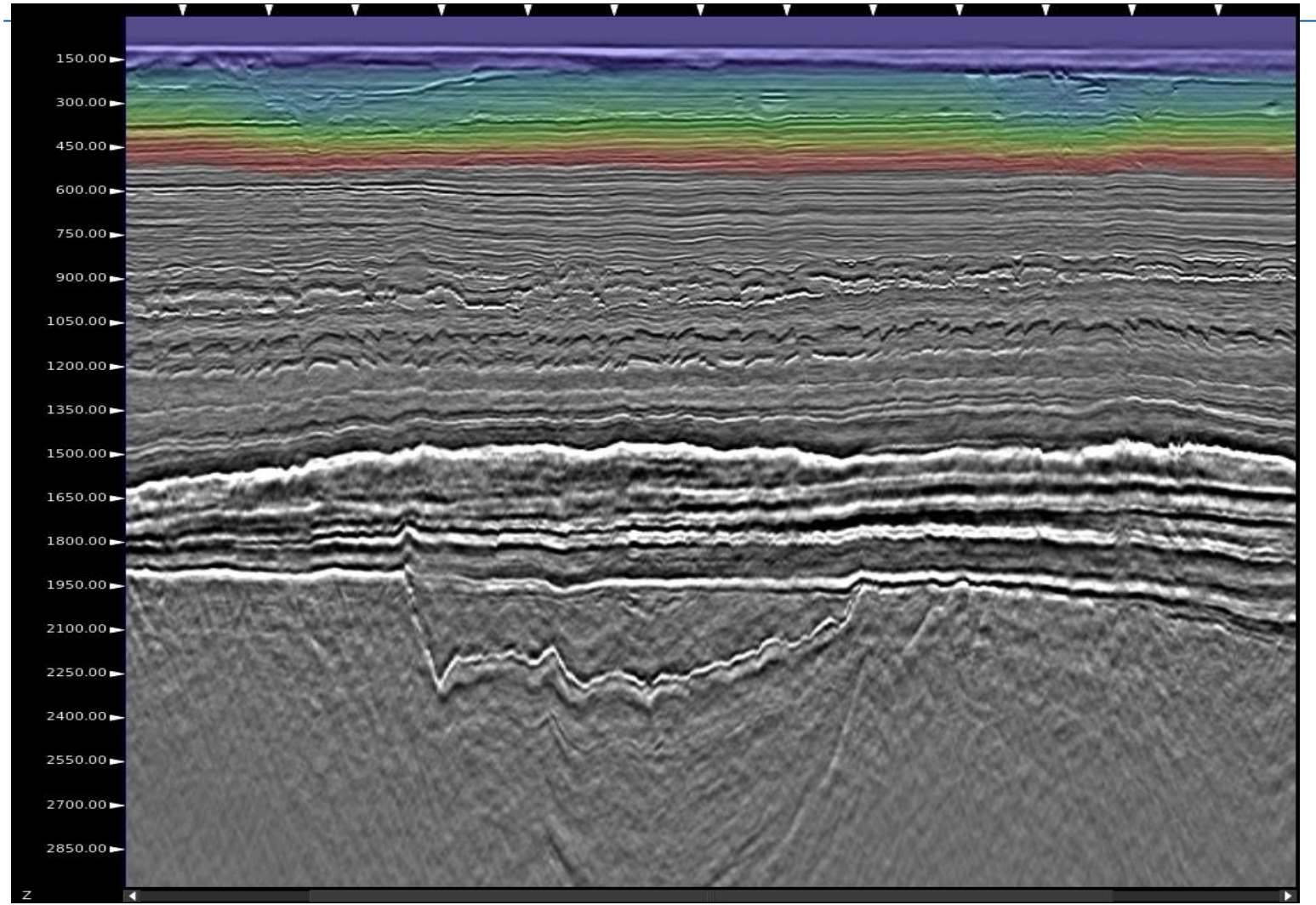
# SWIM 3D view, Z=250 m



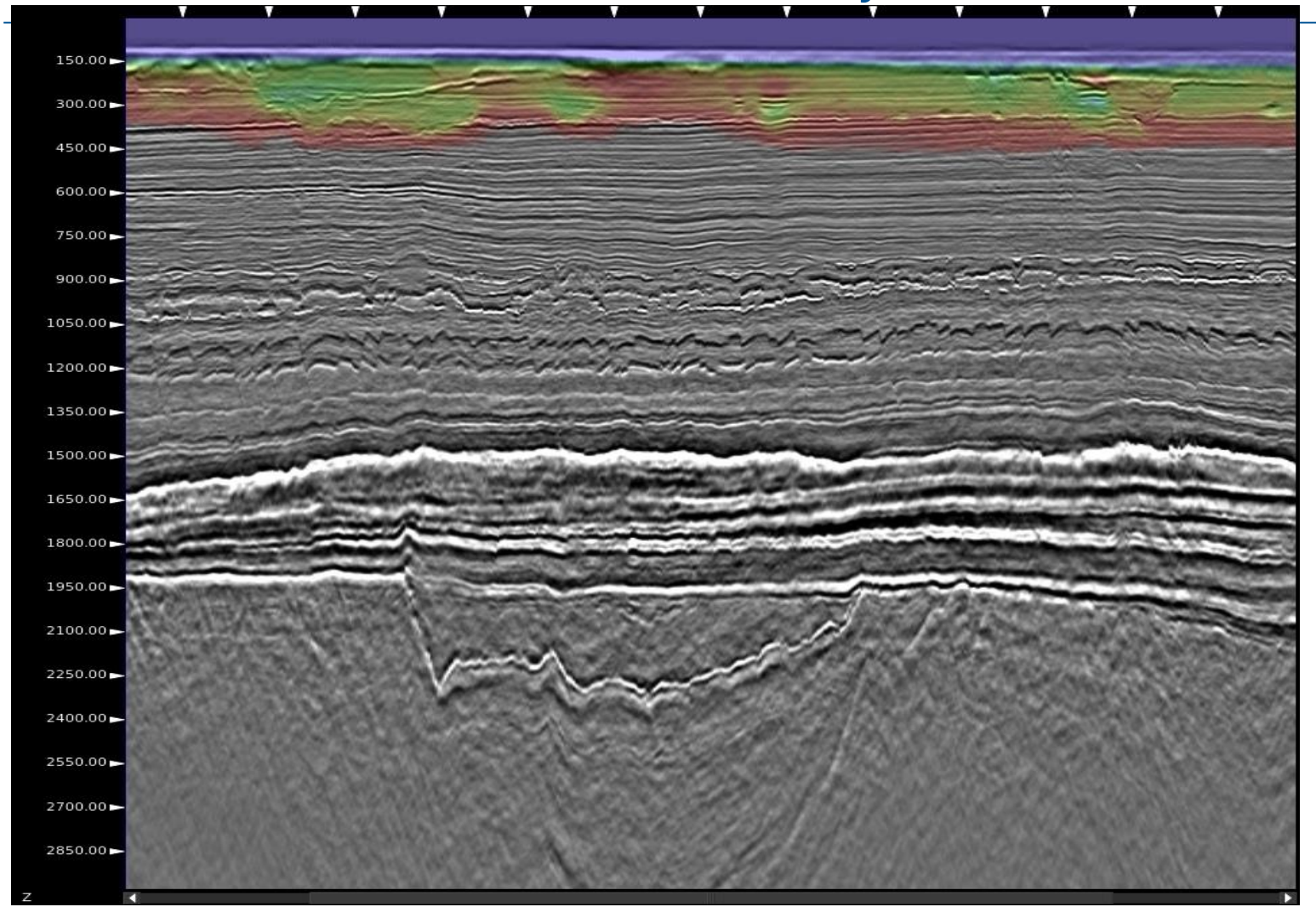
# SWIM 3D view with FWI model overlay



# Kirchhoff PSDM stack – model from wavelet shift tomography



# Kirchhoff PSDM stack – FWI velocity model




**CWI**

- Complete
- Wavefield
- Imaging

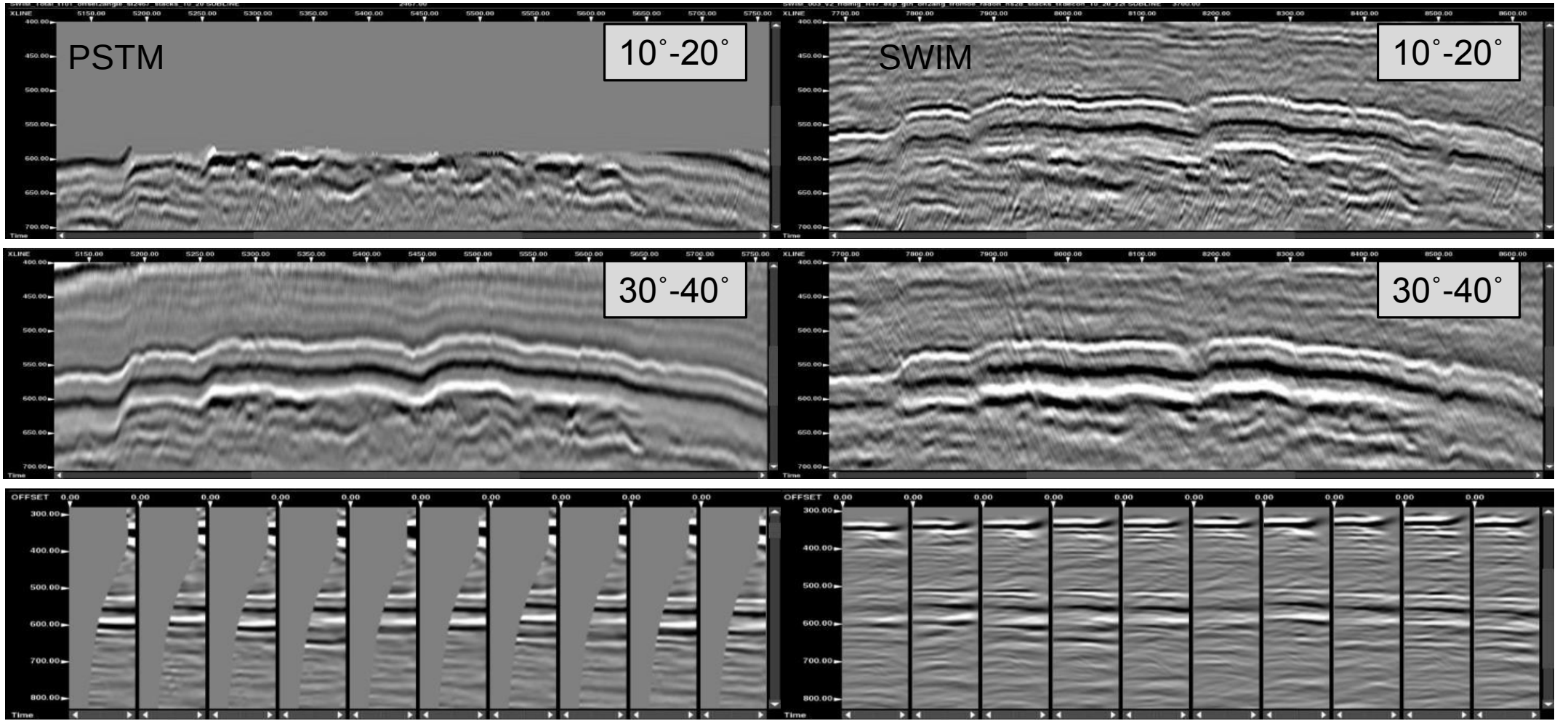
**Using**

- Reflected
- Refracted
- Multiples

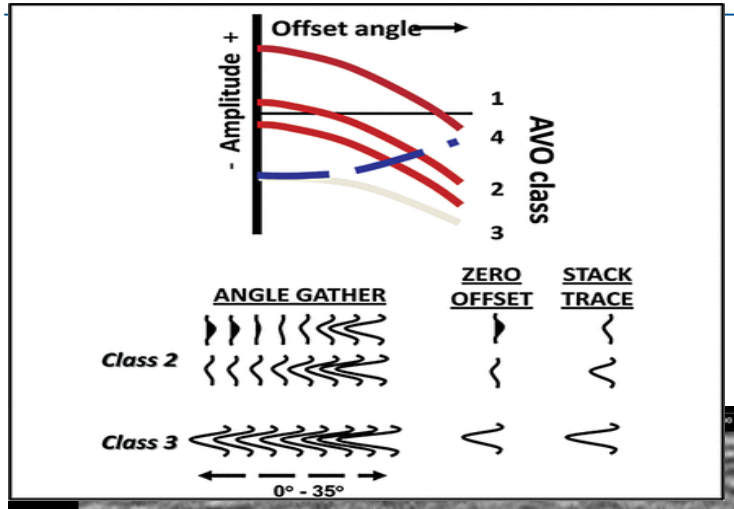
**Build**

- Velocity Model
- IMAGE

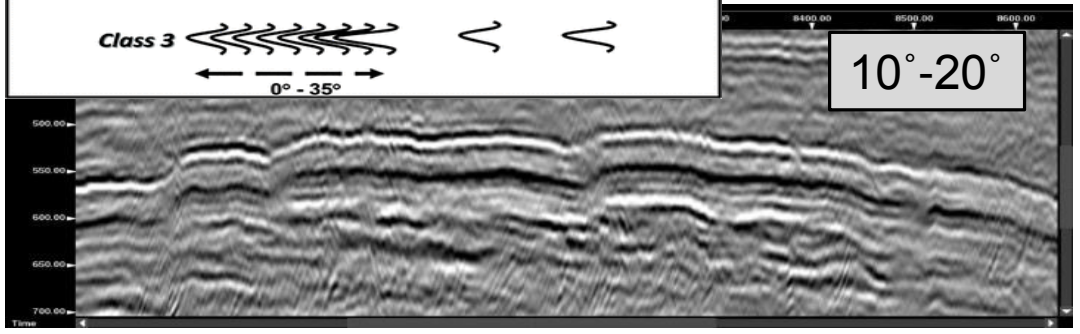
# Angle stacks and gather comparisons

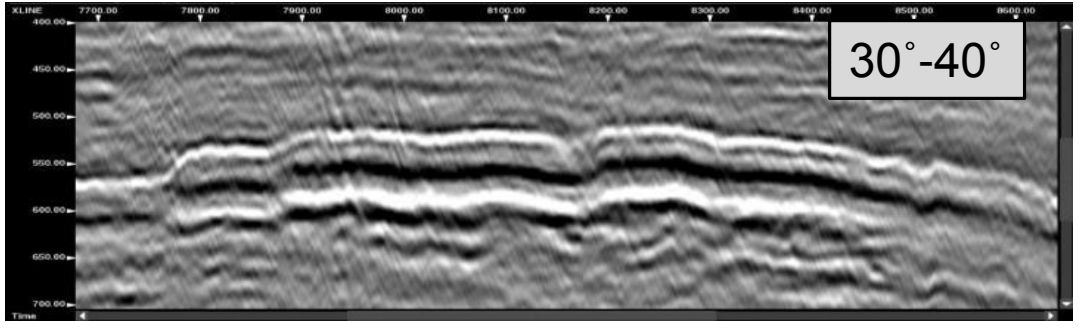


# Amplitude vs Angle

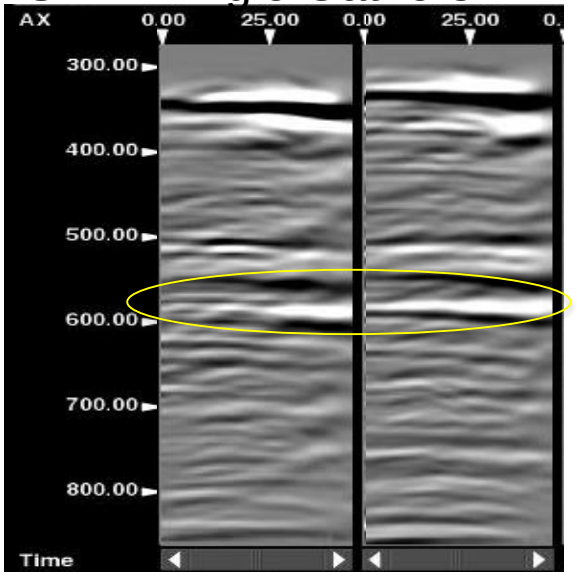


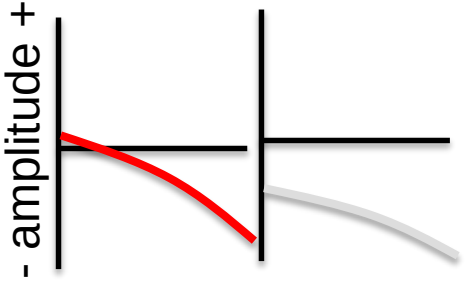

Roden et al. 2012



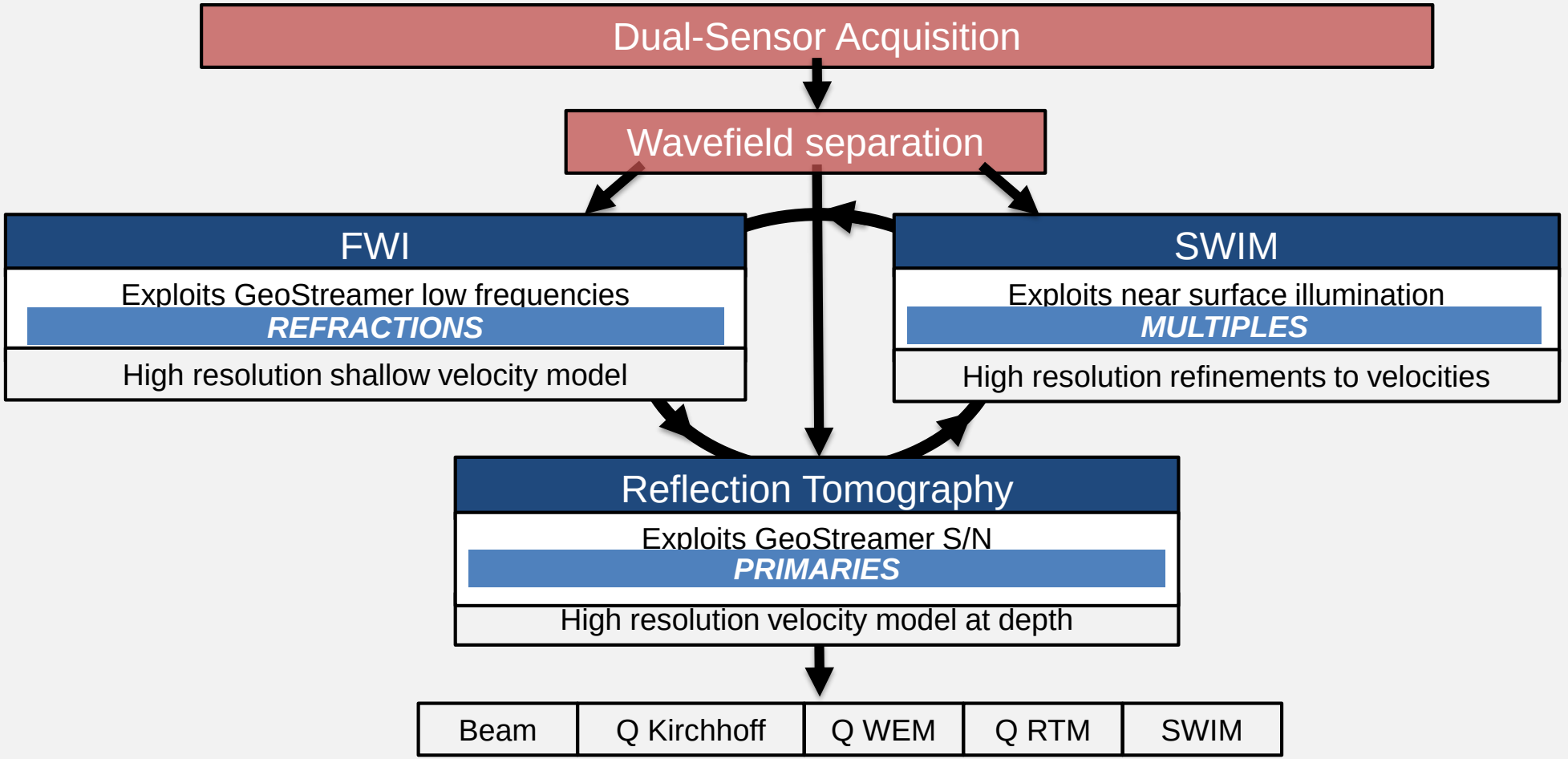




SWIM Angle Gathers

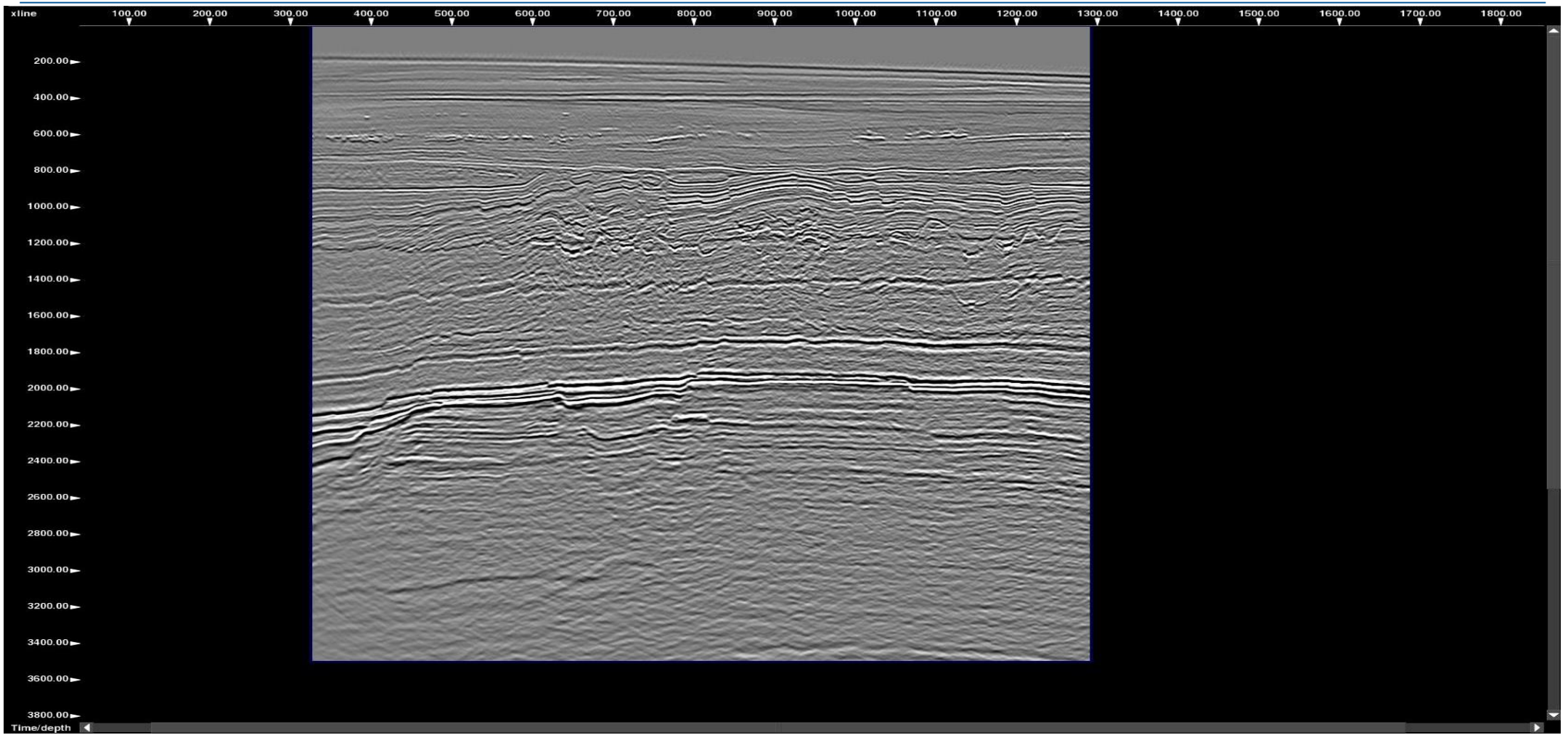


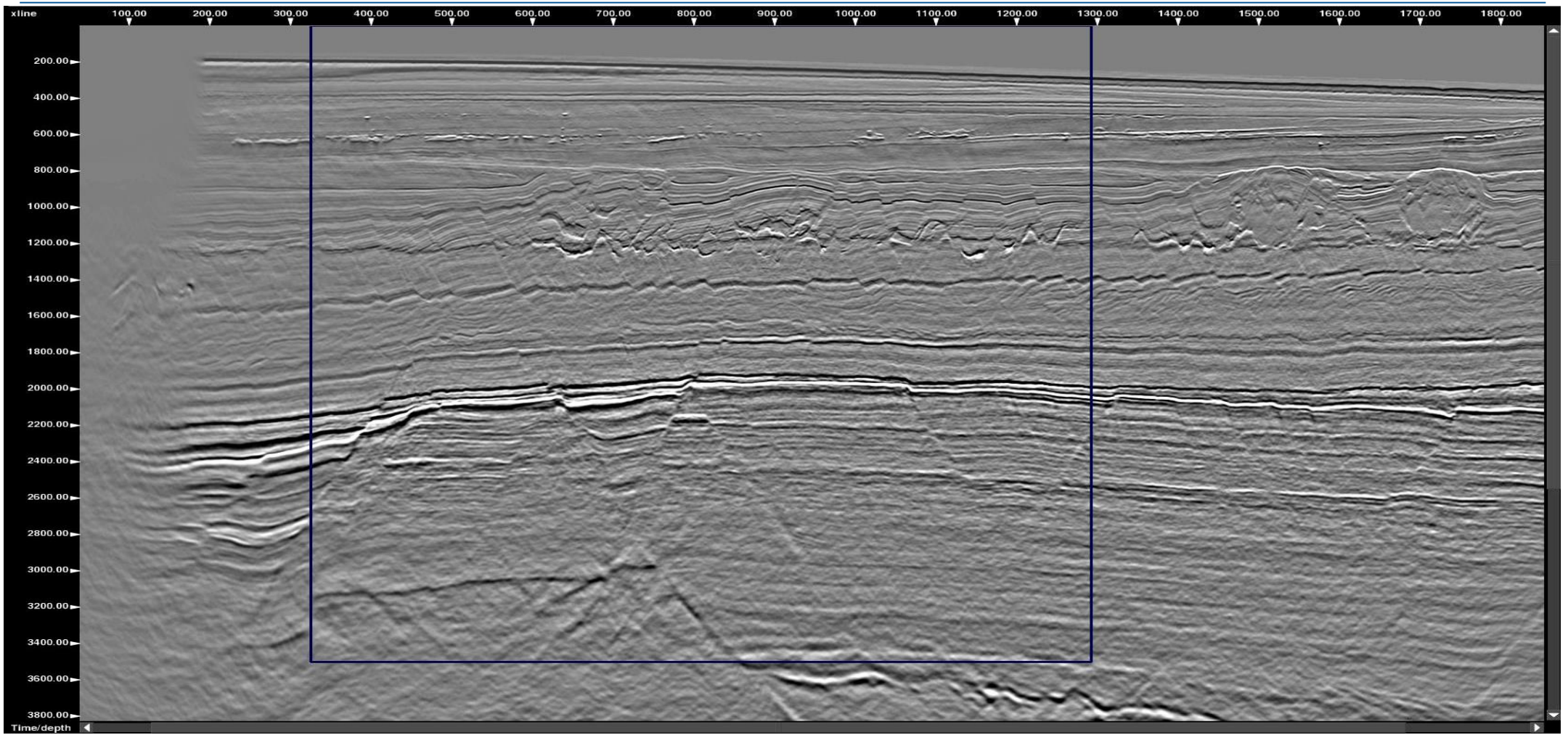
# Complete Wavefield Imaging (CWI)



# Vintage data



# 2014 GeoStreamer – 3D Broadband CWI Q-PSDM



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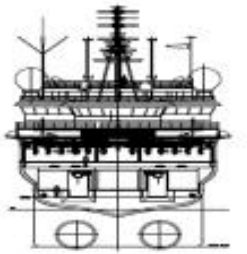
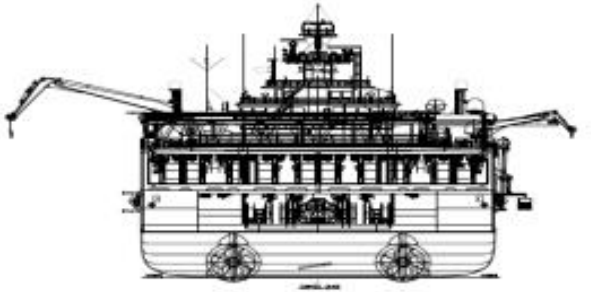


Conventional vessels



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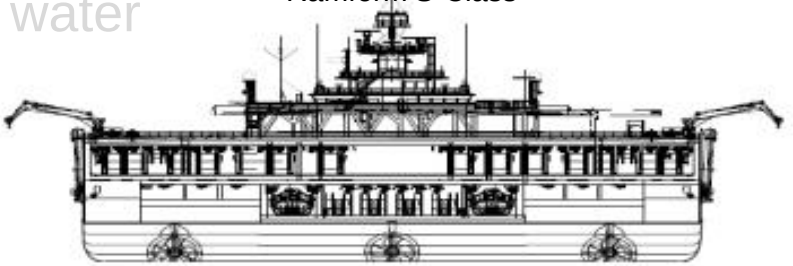
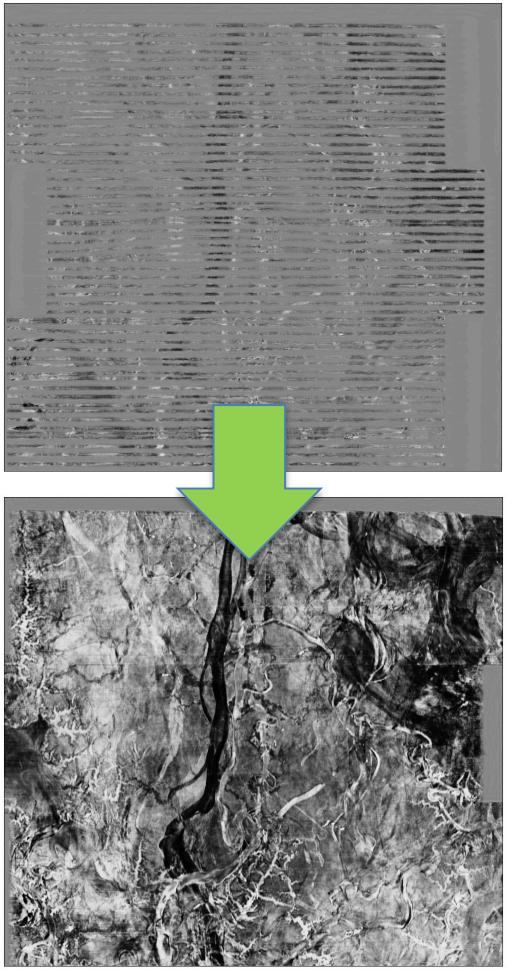


Ramform, Titan

# Conclusions

- Ramform Titan Class takes operational efficiency to yet another level in terms of **deployment, production and retrieval efficiency**.
- GeoStreamer is a proven broadband marine seismic solution with a **10 year track record** with respect to **experience, efficiency, data quality and 4D compatibility**.
- GeoStreamer offers great **flexibility in towing configurations** in order to optimize speed and efficiency without compromising quality.
- Imaging with separated wavefields – **SWIM** – has the potential to become a game changer in both acquisition and imaging.
- **Ramform**, **GeoStreamer and SWIM is a perfect** fit.



# Thank You