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GROUP

# BASMARGE: Basement and Margin Ultra-Deep Imaging Seismic Survey of the Norwegian Offshore Realm

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# Outline

1. Seismic Imaging Challenges;
2. FloatSeis™ Technology;
3. BASMARGE Rationale;
4. BASMARGE Acquisition details;
5. Conclusion

# Seismic imaging challenges

I. **Robust seismic image over complex geological settings:**

- sub-basalts structures;
- prospective sub-salt basins;
- steep bedding horizons;
- carbonate deposits exploration.

II. **Deep target horizons seismic imaging:**

- to perform regional overview and highlight key areas of the further exploration activities;
- to understand the whole basin architecture;
- to perform basin-wide integrated interpretation and basing modeling for upcoming license rounds.

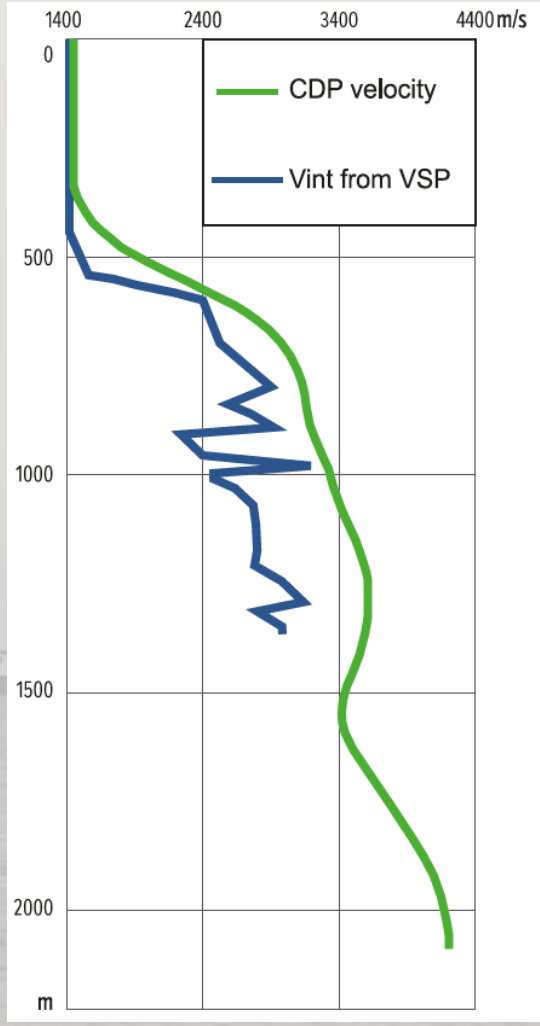
# "CDP" velocities performance

**CDP Velocities "Performance Review":**

- CDP velocities are used in the majority of cases;
- CDP velocities fall within ±15-20% of the true velocities;
- In complex geological environments CDP velocity field tends to be even less reliable

**Geological environments where CDP velocity analysis fails:**

- Sub-salt exploration provinces;
- Sub-basalt sediments and low velocity zones;
- Steep and irregular bedding;
- High-velocity carbonaceous formations;
- "Gas chimney" areas.



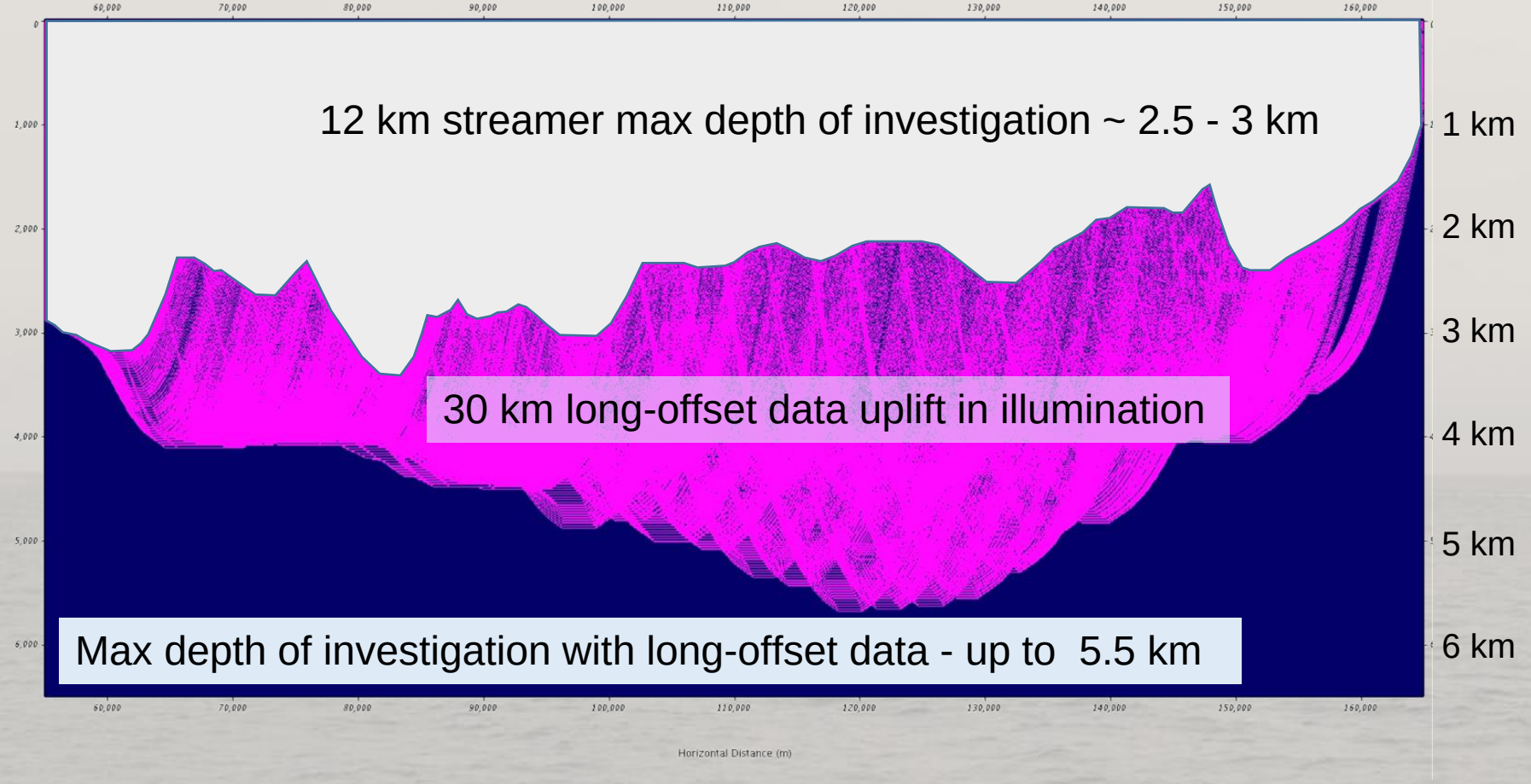
# FWI – a new industry standard

**Ultra-long offset Low Frequency data Full Wave Inversion** (FWI) velocity model building technique gives robust, high-resolution results.

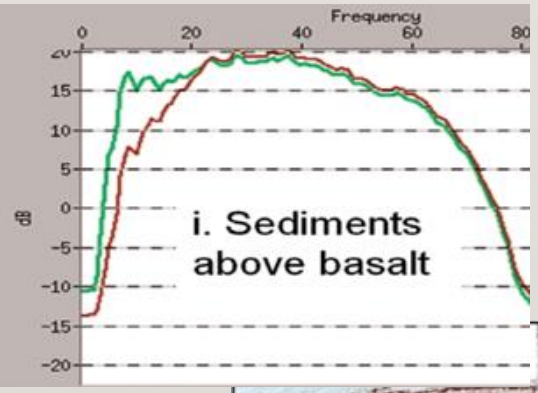
## Widely accepted rules are:

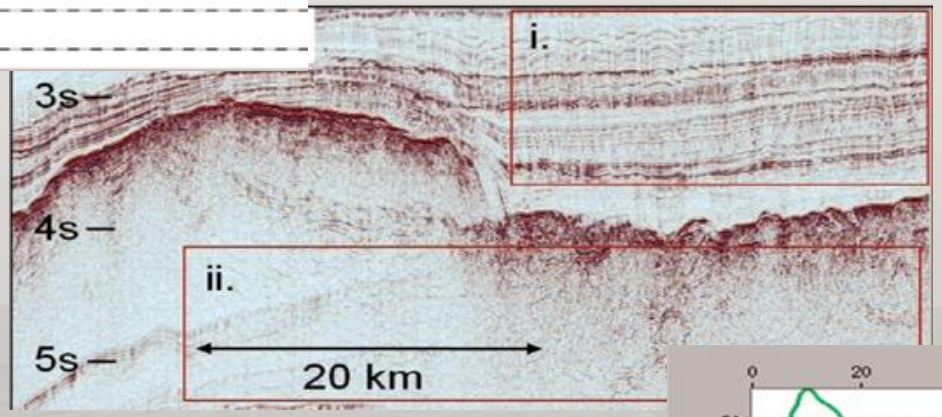
- Lack of **long offset data** negatively influences FWI in terms of illuminating more subsurface angles and deeper sections;
- FWI application requires **low frequency components** to avoid cycle skipping problem and ensure a robust solution.
- **Depth of FWI inversion is 1/4–1/6 of recorded offsets.** At least 30 km offsets are needed for 5-7 km depth solution.

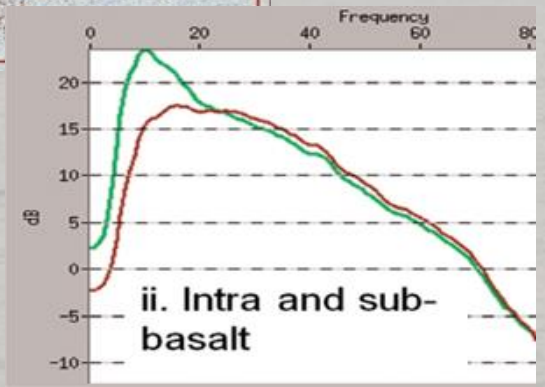
# Importance of long-offsets for full-scale FWI



# Frequency spectrum to go deeper



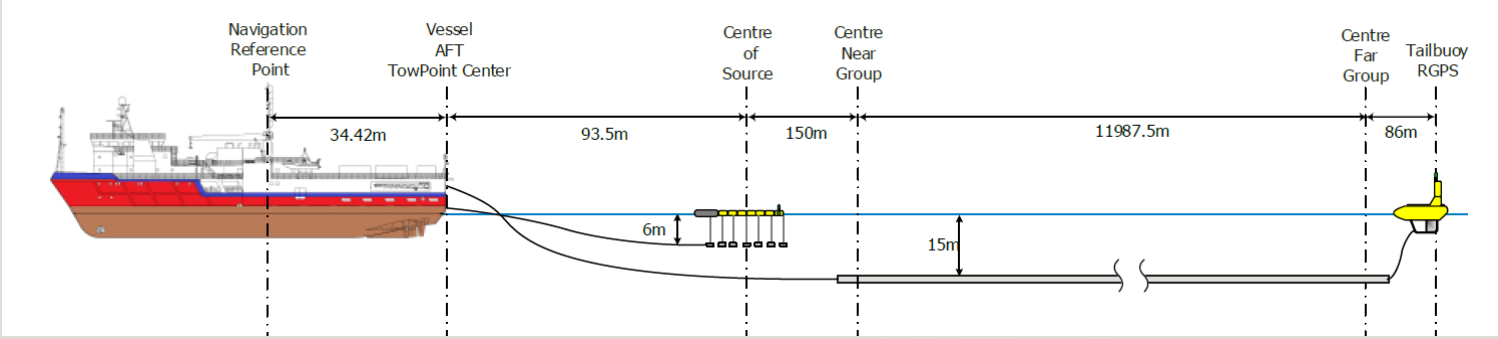




**Dominant Frequency:**

- Above basalts – 30-40 Hz;
- Sub-basalts – 10-15 Hz

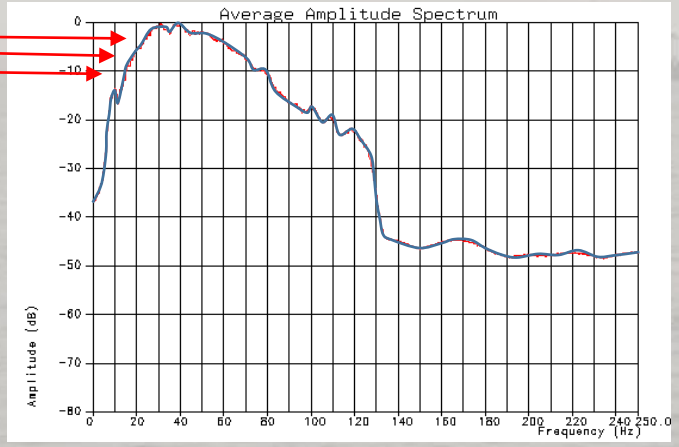
# Technical limitations

## I. Offset limitation (<12 km) of towed seismic streamers:




## II. Weak low-frequency (<15 Hz) component:

!!!

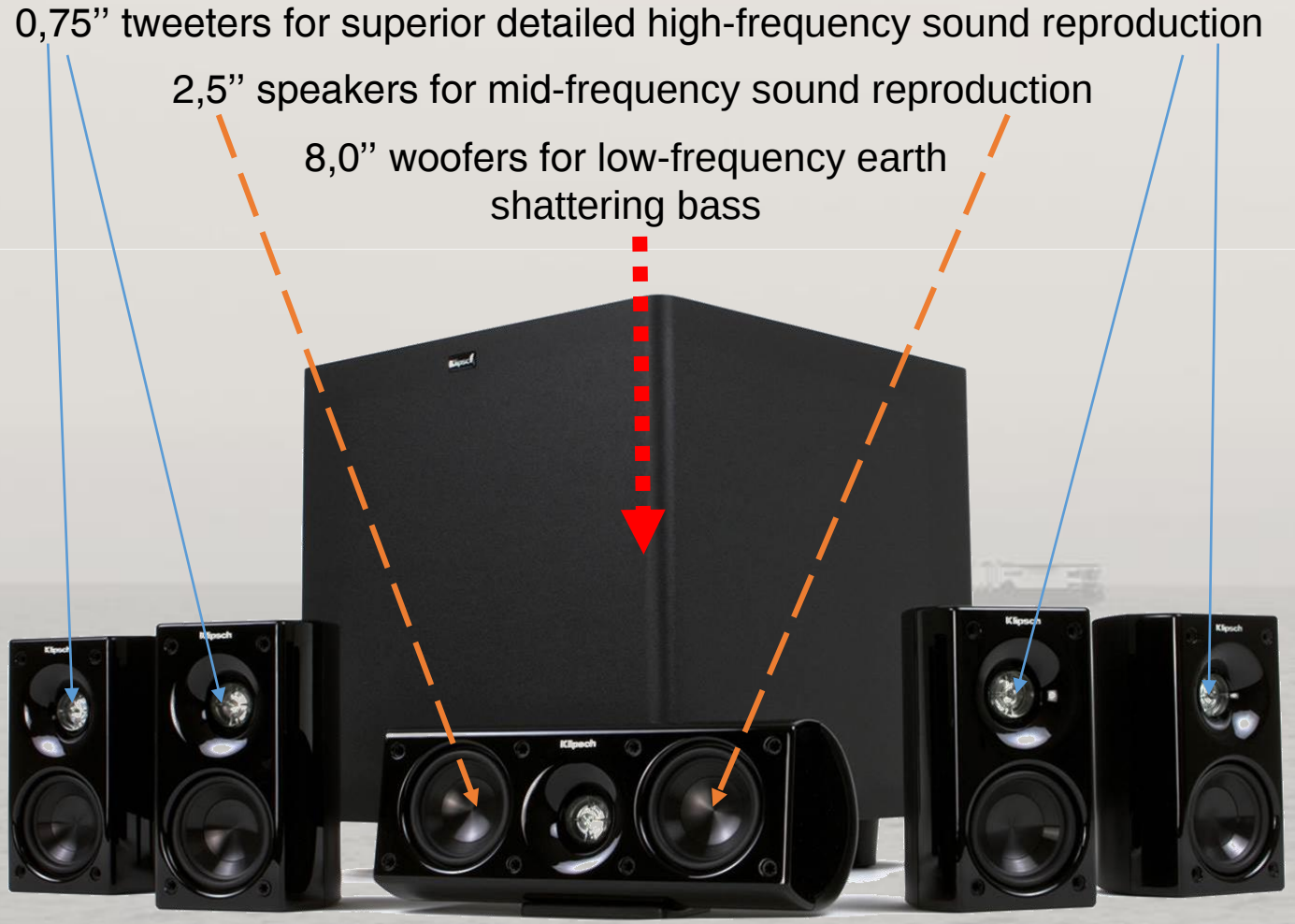


# Available long-offset techniques

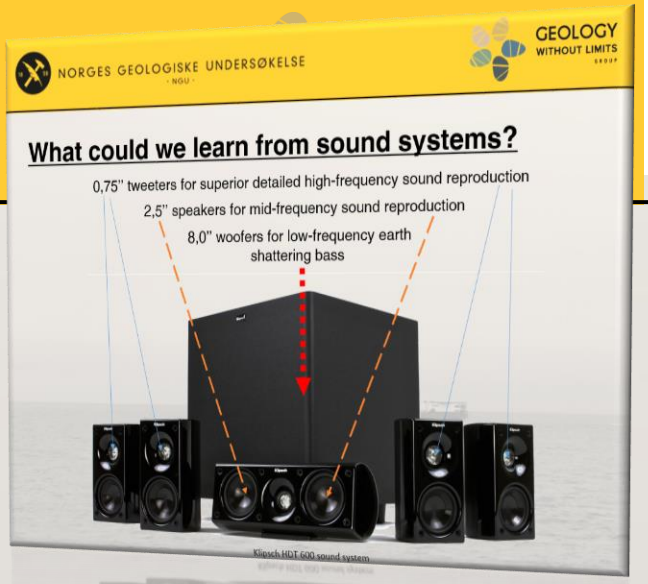
| | OBN/OBC | Multi-vessel surveys |
|---|---|---|
| No limitations on recording offsets | ✓ | ✗ |
| No limitations on water depth | ✗ | ✓ |
| Precise positioning | ✗ | ✓ |
| Real time tracking and QC | ✗ | ✓ |
| Eco & fishing activities friendly | ✗ | ✗ |
| Portable solution | ✓ | ✗ |
| No need for specialized vessels | ✗ | ✗ |
| High production rate | ✗ | ✓ |
| **Cost-effective** | ✗ | ✗ |

# How to emit low-frequencies?

# What could we learn from sound systems?




*Klipsch HDT 600 sound system*



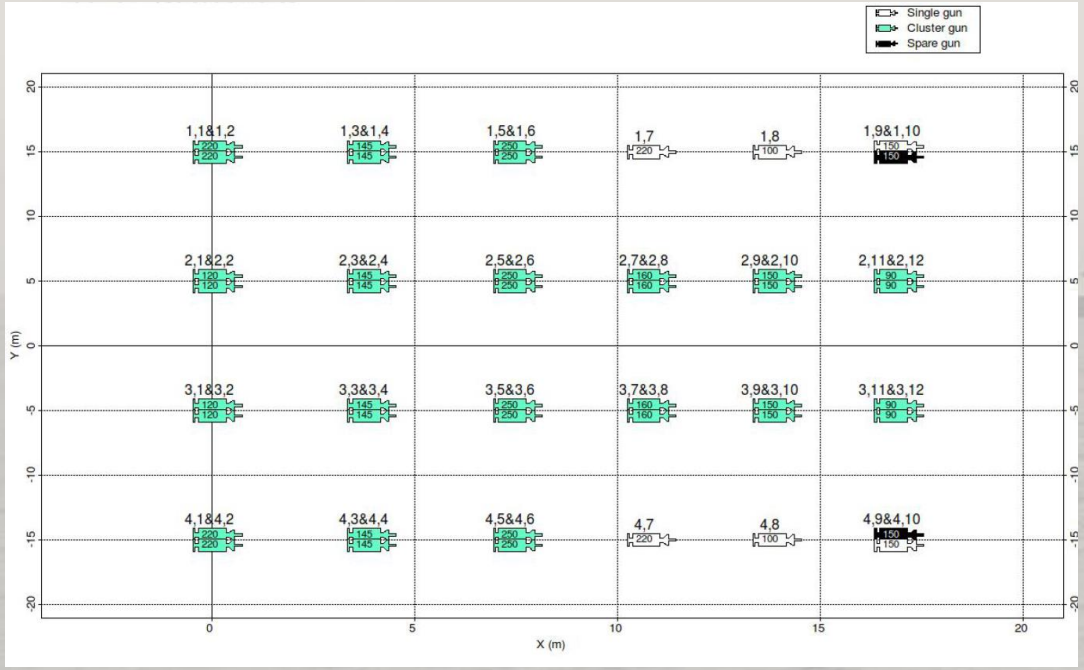

# Standard gun arrays

**Gun array of total volume: 7060 cu. in:**

-- 60-100 cu.in “tweeters” for **high-frequency** = 6 guns

-- 100-250 cu.in guns for **mid-frequency** = 38 guns

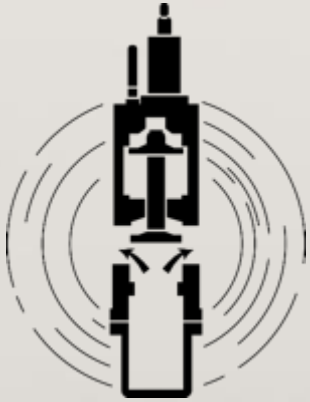
-- 1000+ cu.in woofers <u>for **low-frequency** emission = **0 guns!!!**</u>



# Tools for long-offset & low-frequency recording

**GWL Seismobuoy™**

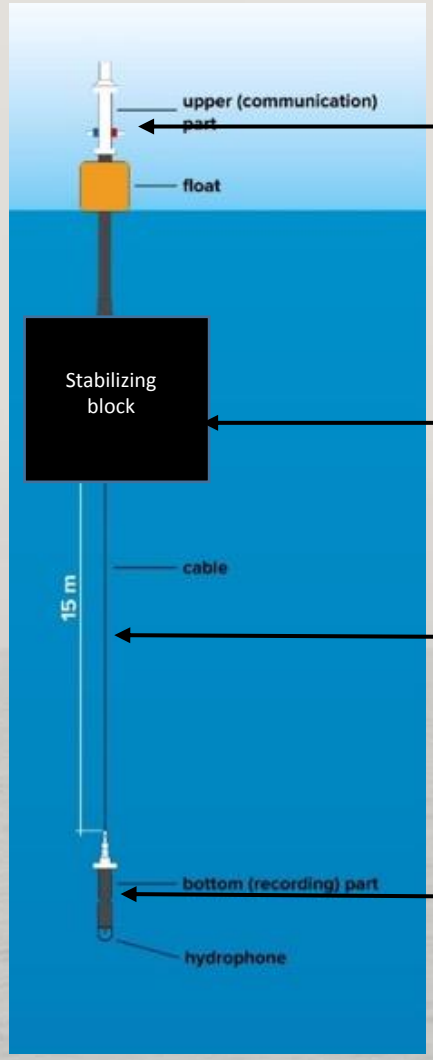
**ultra-long offsets recording device**



**LF Source™**

**low frequency energy emission**

# Seismic recording unit




- **Constant GPS tracking**
- **Real-time telemetry and Quality Control**
- Quick deployment and recovery

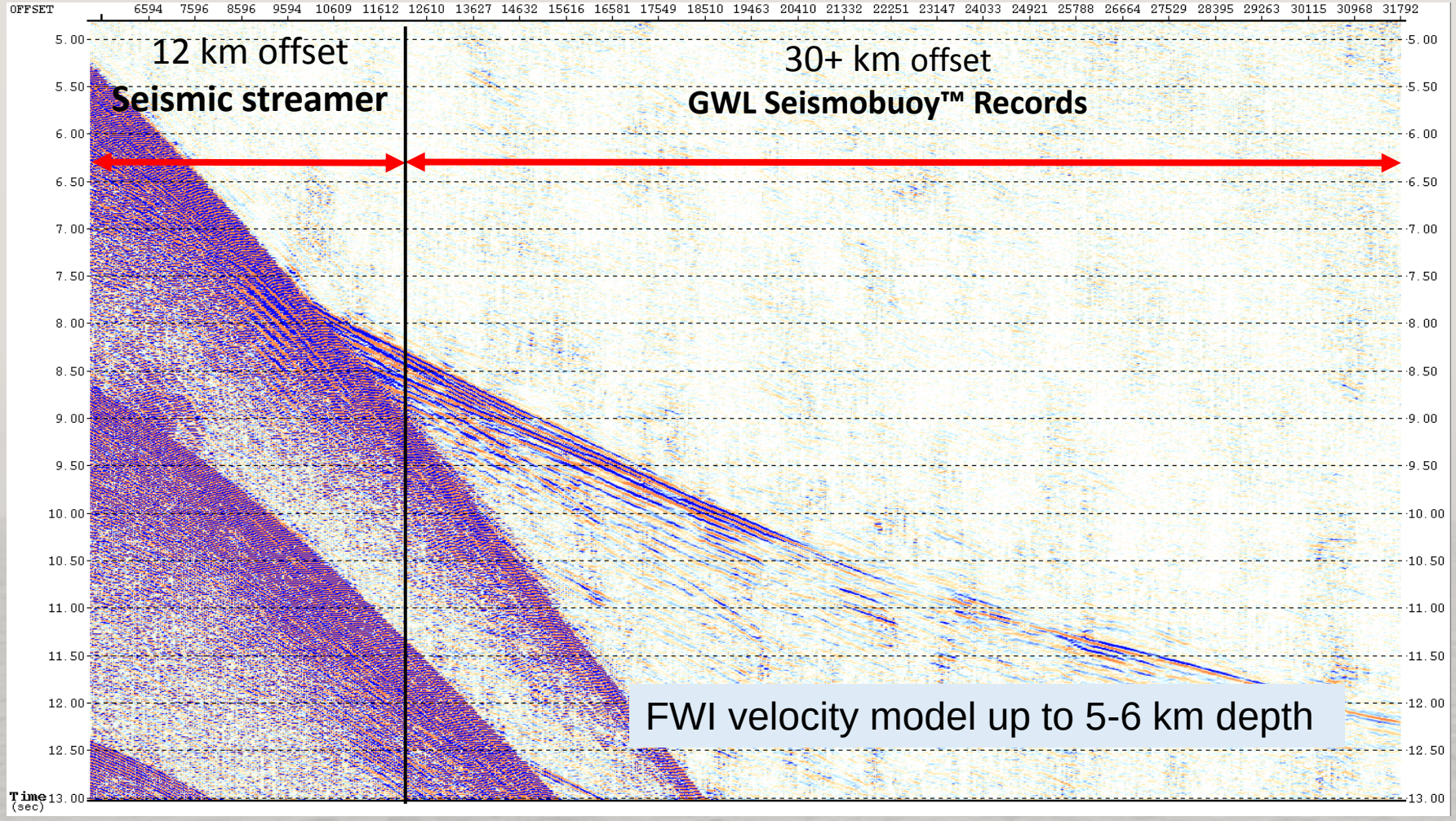
- **Drifting stability**
- **Swell noise attenuation**

- Variable hydrophone depth (up to 15 m)
- Cable with hydrophobic filling

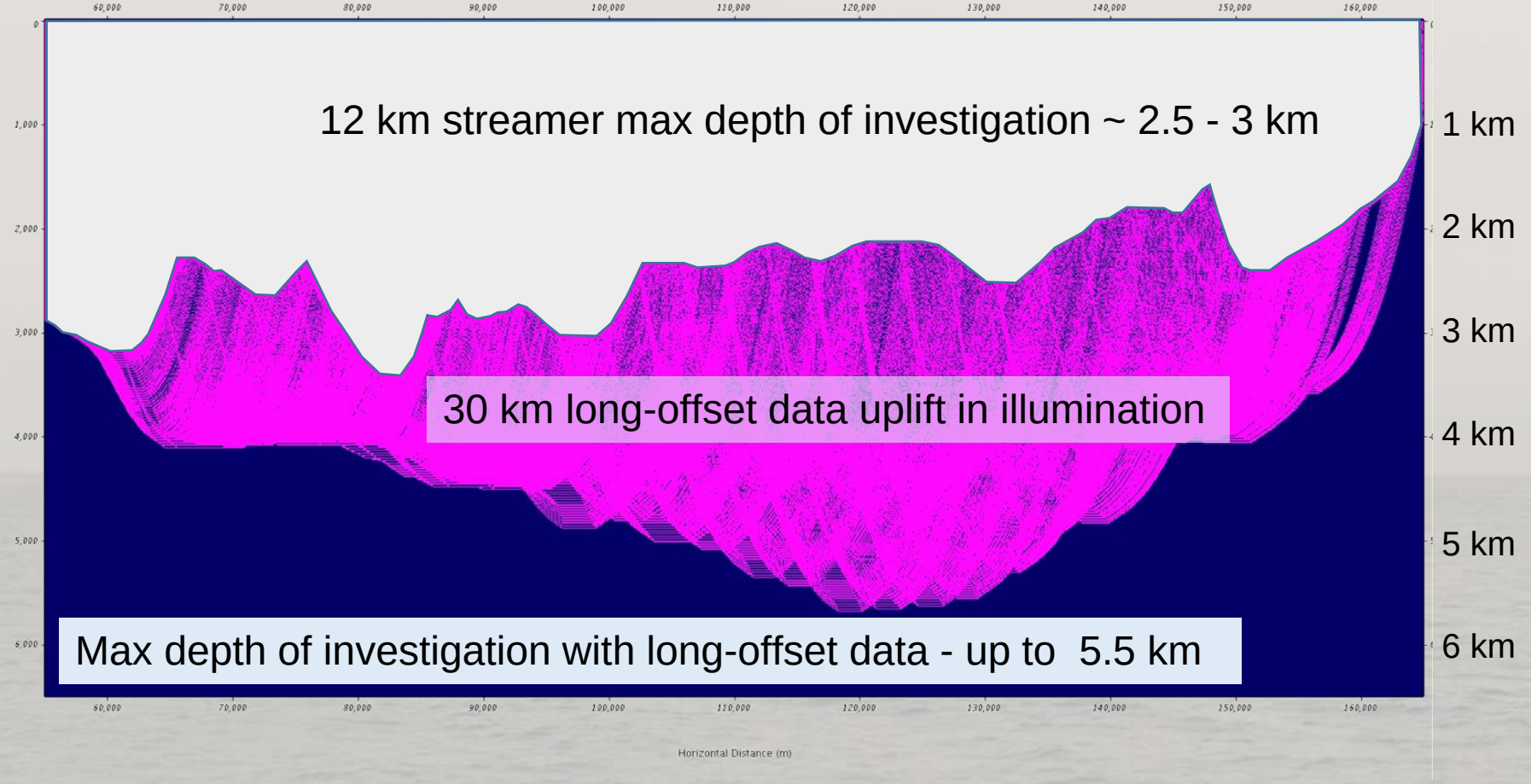
**Low Noise Broadband ADC**

- **High sensitivity hydrophone**
- Non-volatile data storage

# Long-offset record sample



# Importance of long-offsets for full-scale FWI



# LF Source™

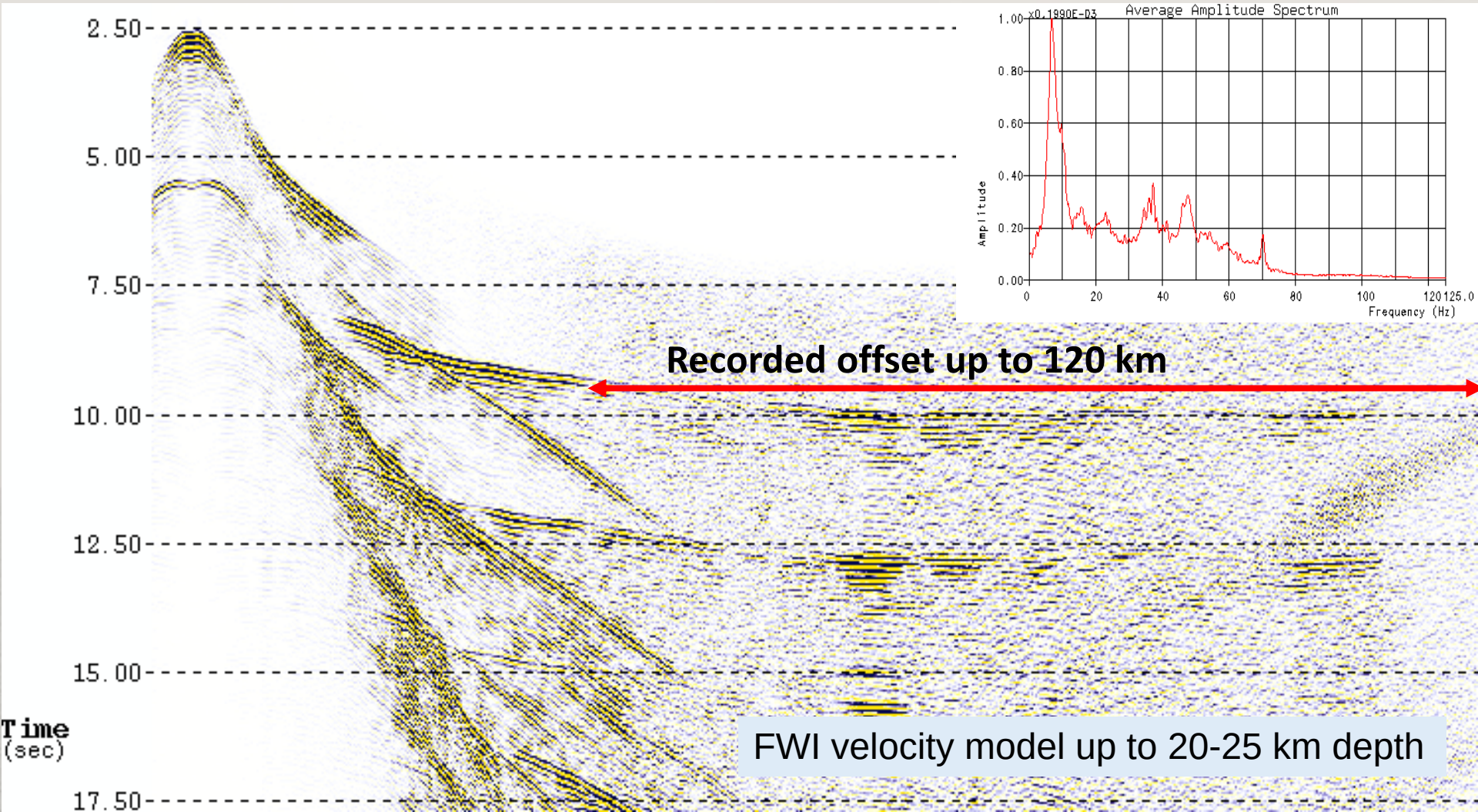
Possible array volumes: 2440/4880/7320 cu. inch.

- Compatible with the majority of existing gun-controllers;
- **Portable container based solution** – easy-to-transport, assemble and install;
- Industry recognized utility sensors;
- Improved inner construction of the source;
- **High signal stability**;
- **Innovative firing system**;
- Fish and mammals friendly;
- Cluster system with improved durability and signal stability;

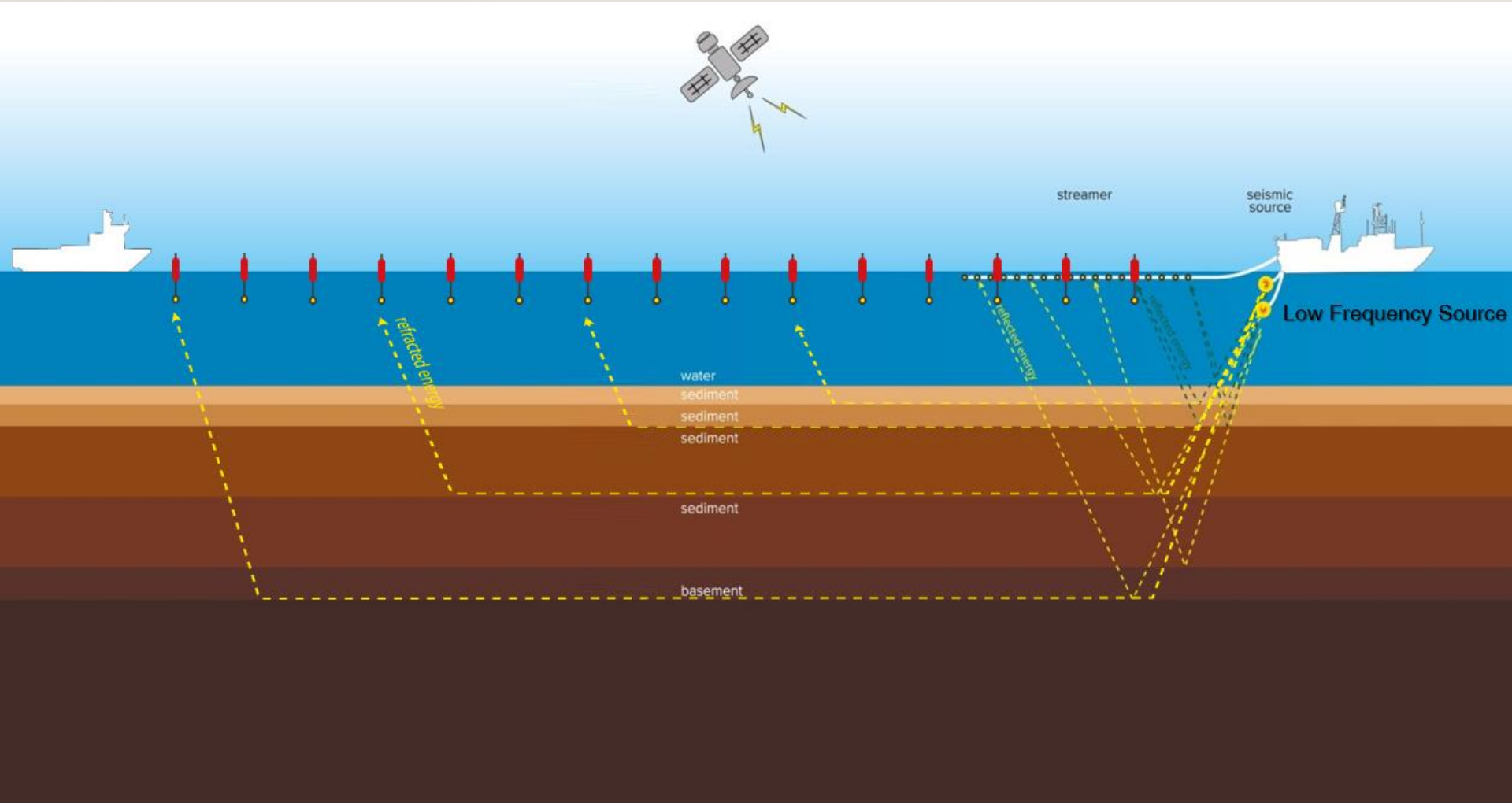
**Standard air guns' volumes vary 40-460 cu.in**

**We suggest to add 2400 cu.in guns into the acquisition to finally get low frequencies!**

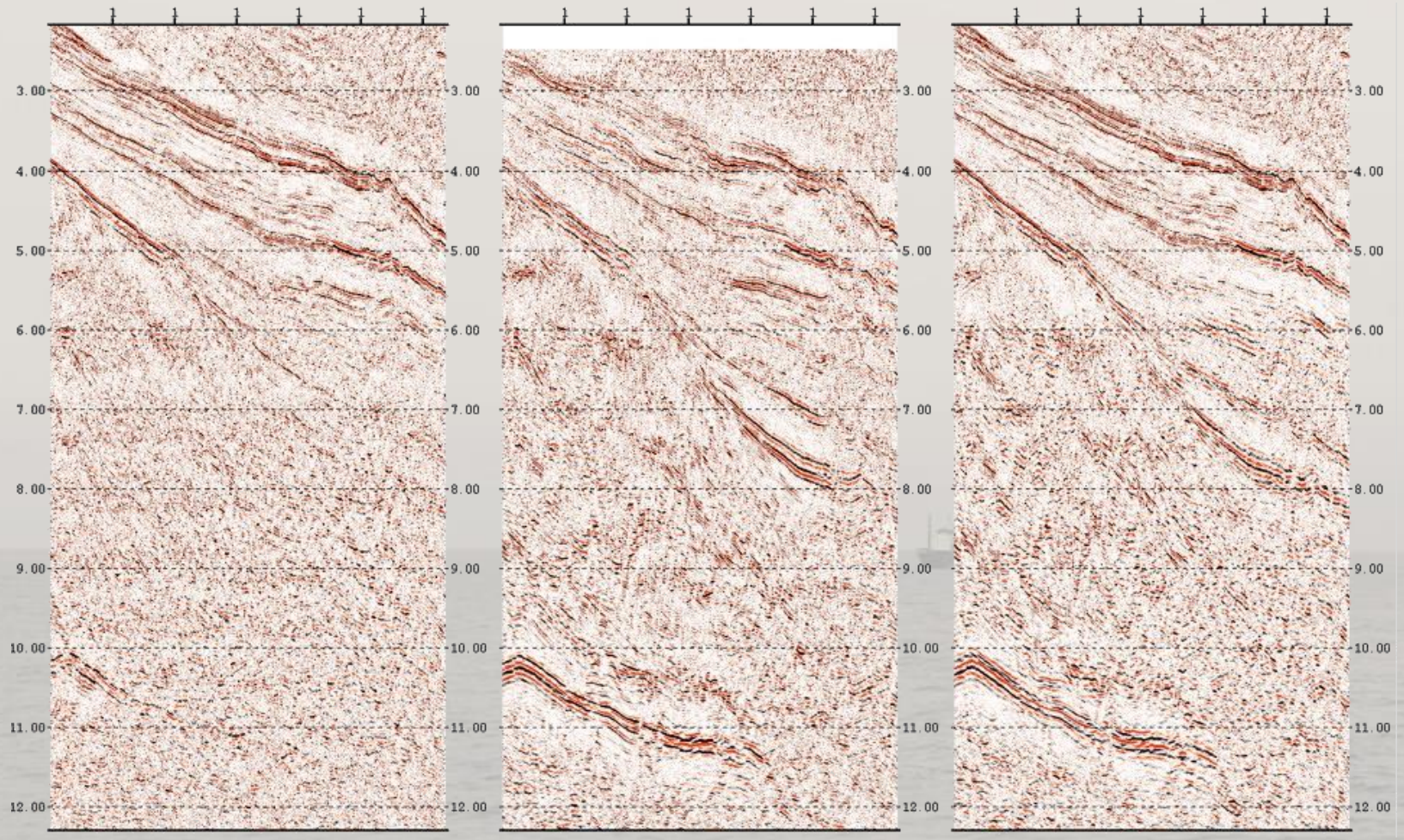
# Ultra long-offset record sample



# FloatSeis™ acquisition technique

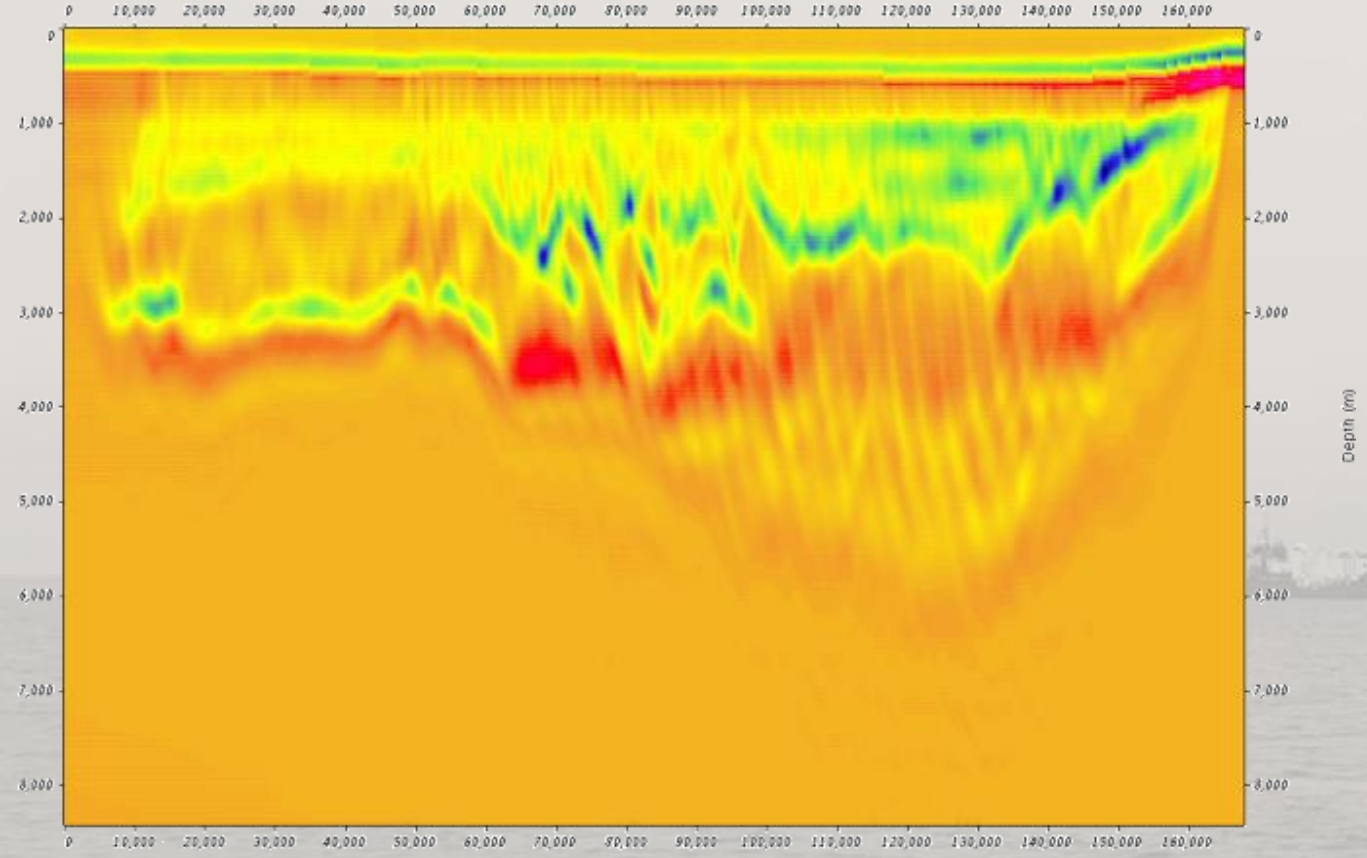


# Acquired results



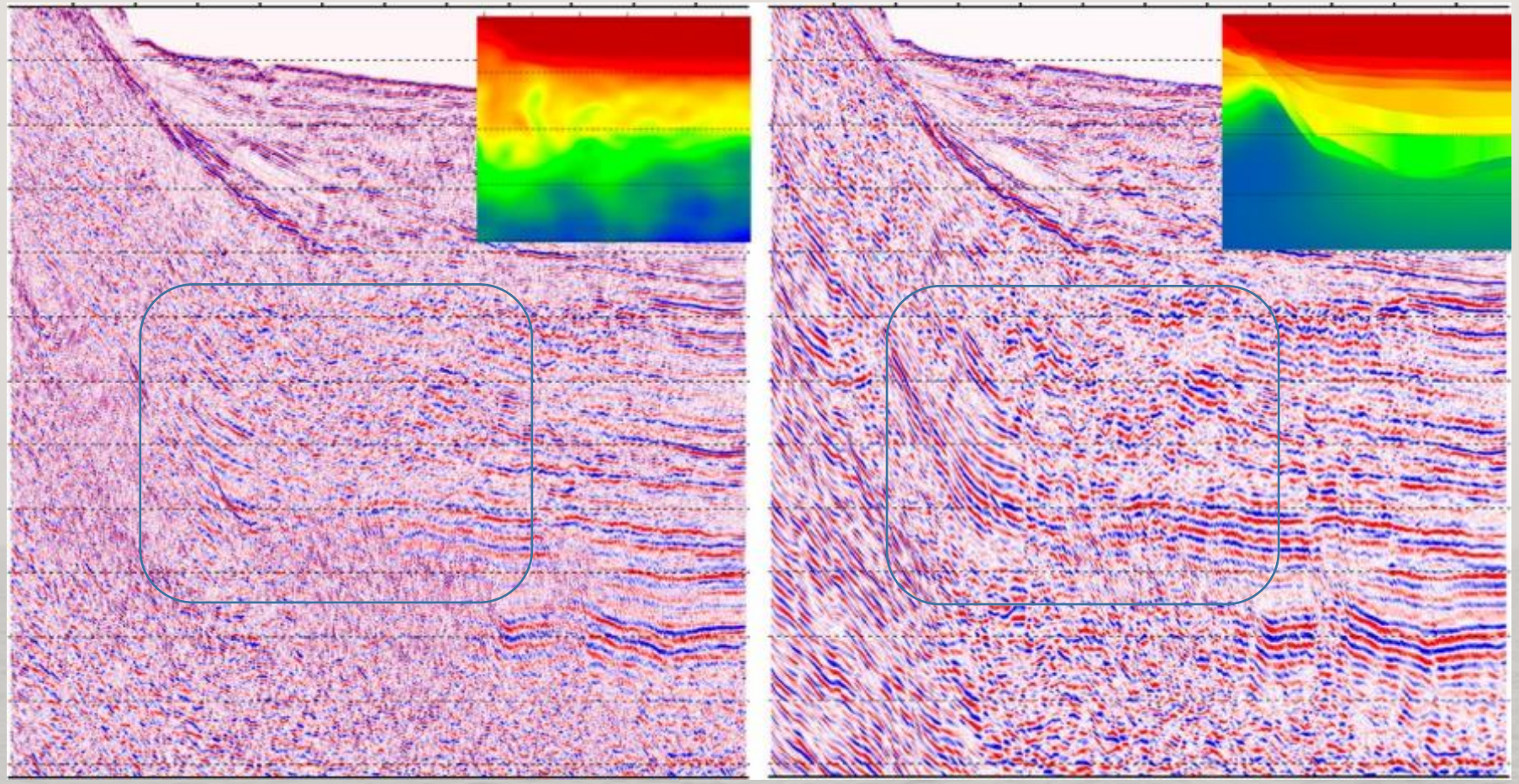

Standard Source | Low Frequency Source™ | Final combined image

# Acquired results

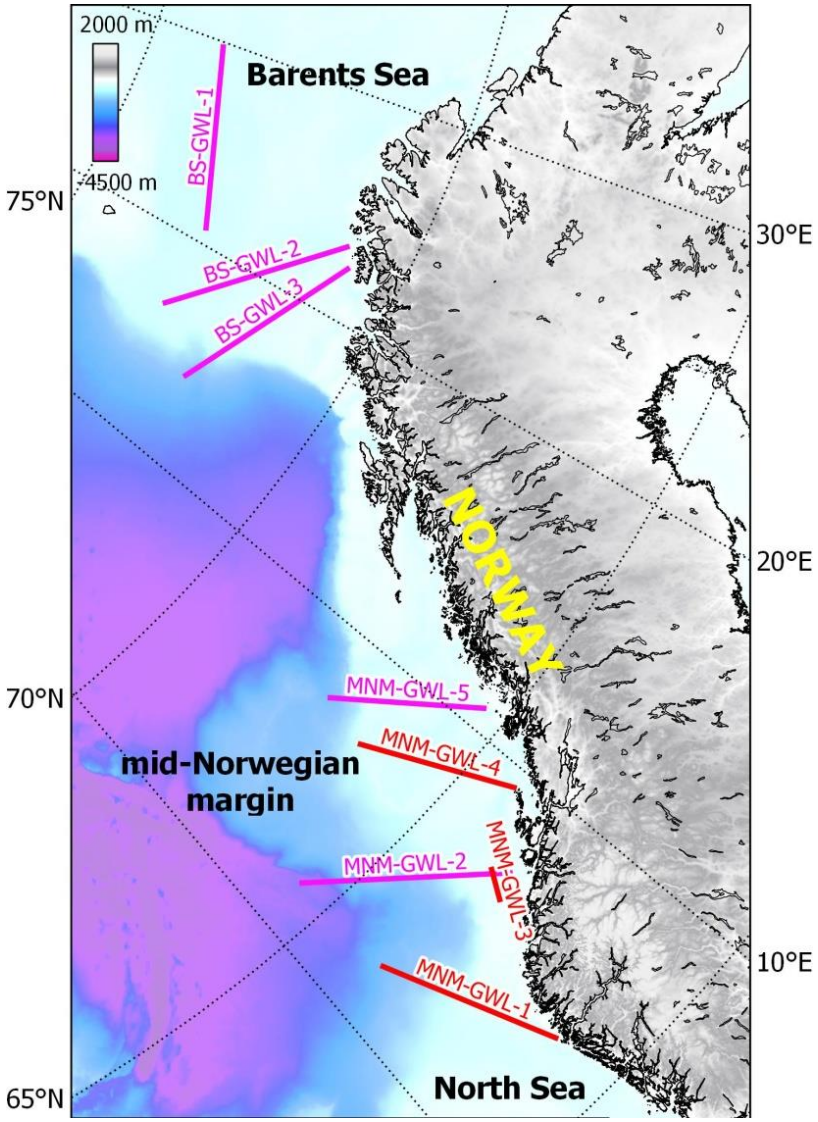



*FWI velocity model obtained with help of long-offset data is well resolved and can be used for initial geological interpretation itself. The high velocity carbonate layer is prominent on the velocity section itself (in blue) and decently corresponds with the available well data.*

# Uplift in seismic image



Dominance of diffractions and steep dips reduce veracity of velocity analysis by reflected waves. Thus, quality of velocity spectra might be relatively low (on the left). Inclusion of long-offset low-frequency based velocity model on the migration stage allows to enhance wavefield quality in zones with complex geological structure (on the right). It is clearly seen that the clarity of the seismic image and the quality of reflecting horizons tracing were enhanced.

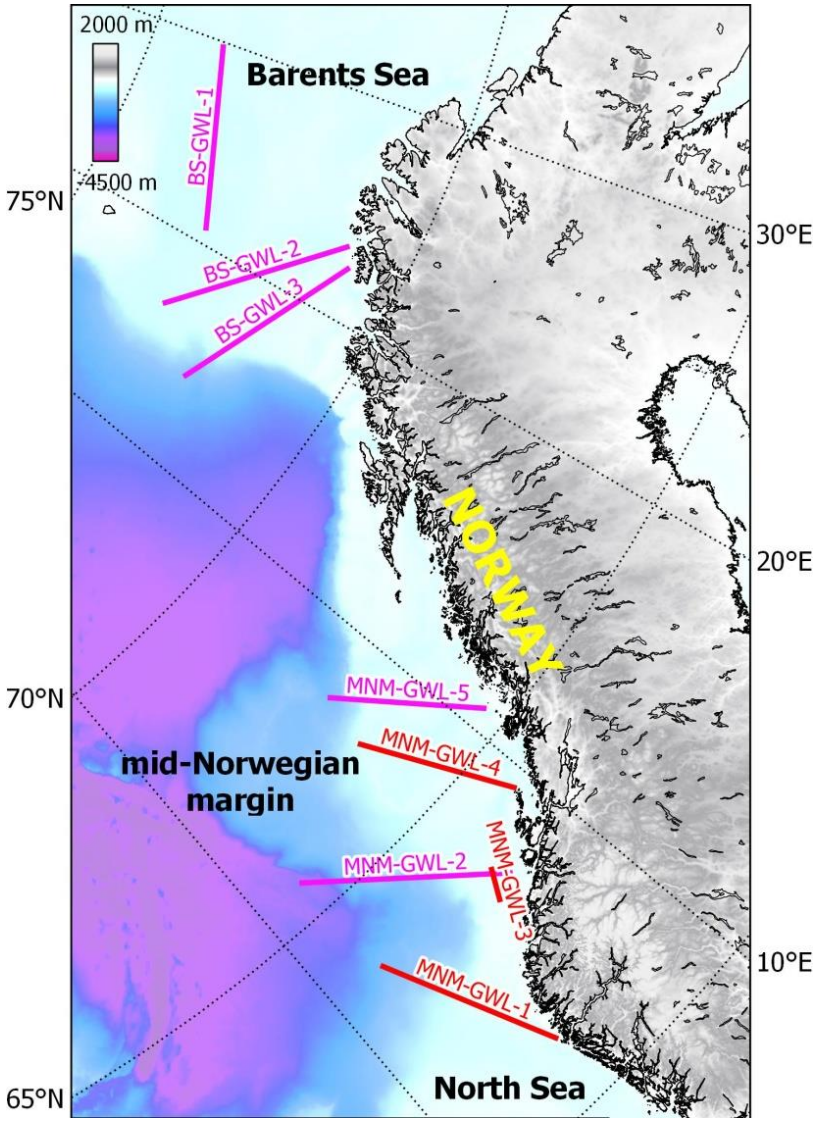



# Project Overview:

**Project content:** 3-8 ultra-deep seismic lines
**Project duration:** 1 year
**Starting date:** May 2019
**Price for early participants:** 200.000 USD

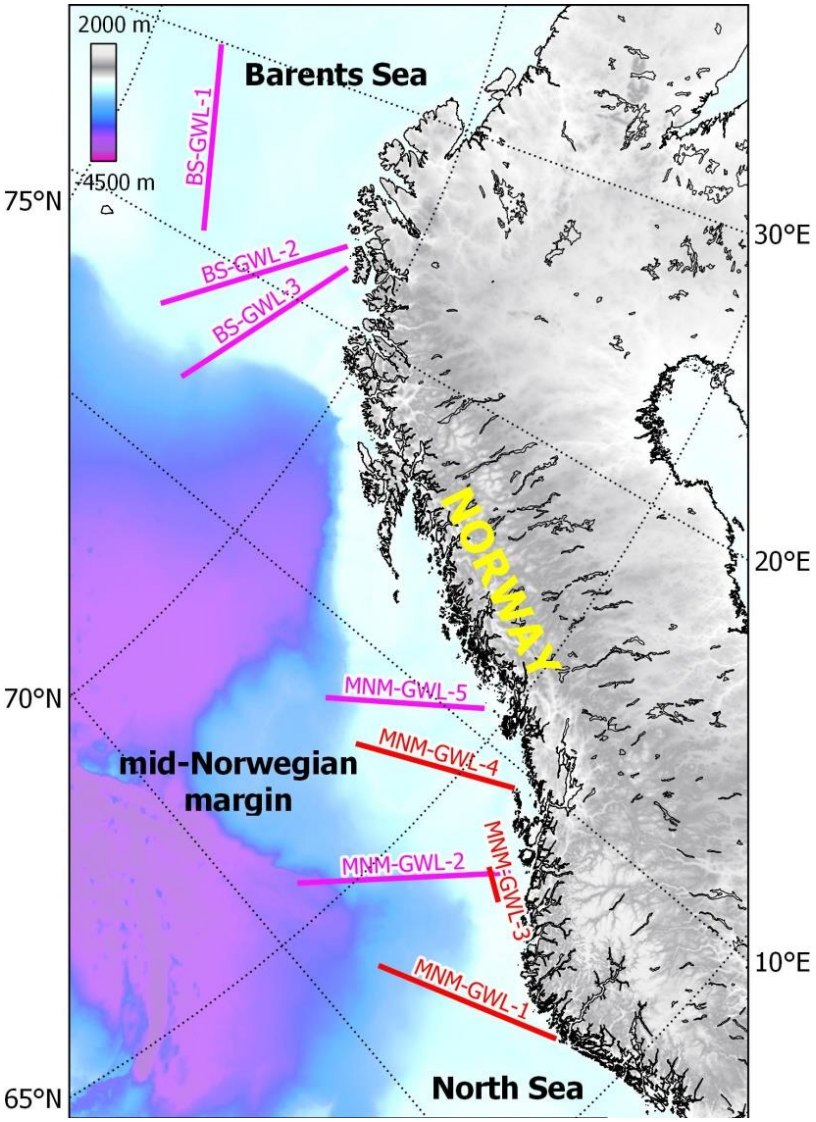
# Main Objectives:

- Shed light on the deep basement structures, sub-basalt and sub-salt features;
- Improve the understanding of the tectonic, crustal and sedimentary basin evolution of the Mid-Norwegian Margin and the Barents Sea;
- Validate FloatSeis™ technology for broad application offshore Norway.



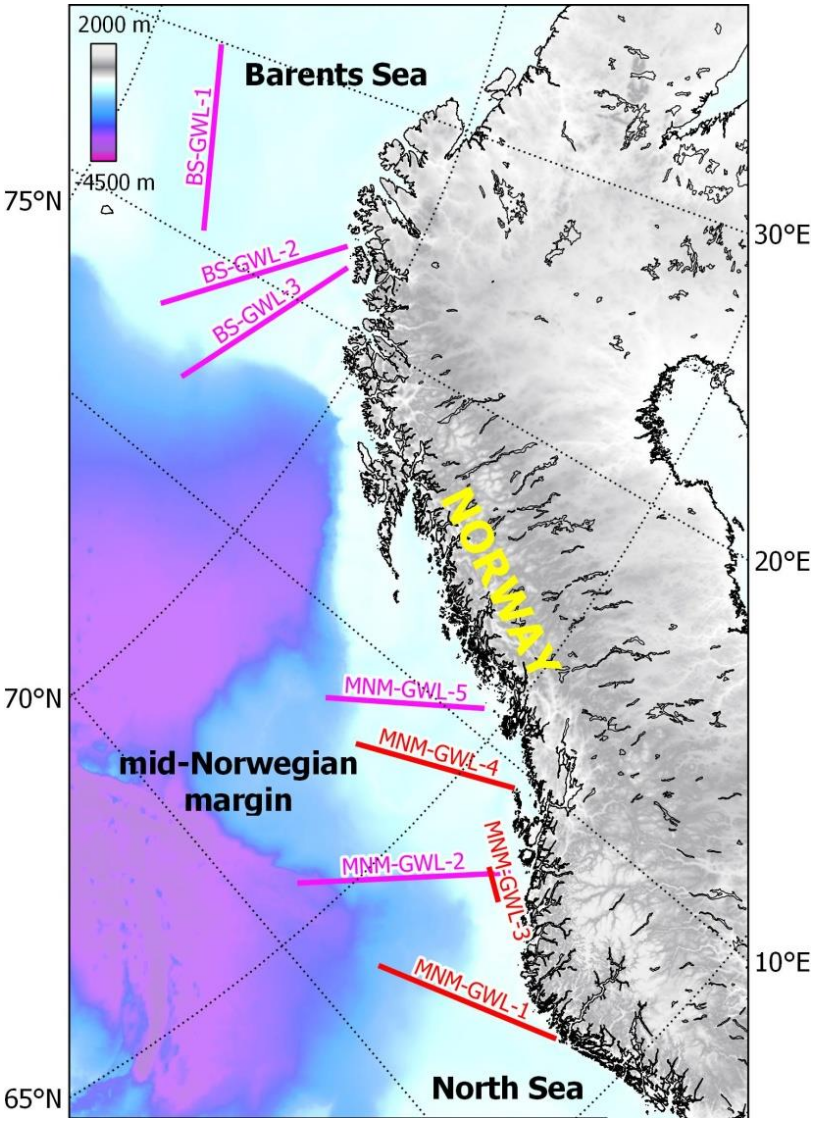

# Geological Context

**MNM-GWL-1:** runs from the Northern North Sea up to the continent-ocean transition of the Møre margin. The survey attempts to **better constrain the basement geometry** associated with the offshore prolongation of the Møre Trøndelag Fault complex and the associated transition zone between the platform domain and the deep Cretaceous sag basin formed in Late Jurassic-Cretaceous. The respective sharp transition and steeply dipping layers are a classic challenge for standard seismic imaging. To the west, the transect will partly **tackle an eminent sub-basalt/sub sills imaging problem**. This issue has up-to-date not allowed us to properly understand the basin configuration near the large basaltic province.




# Geological Context

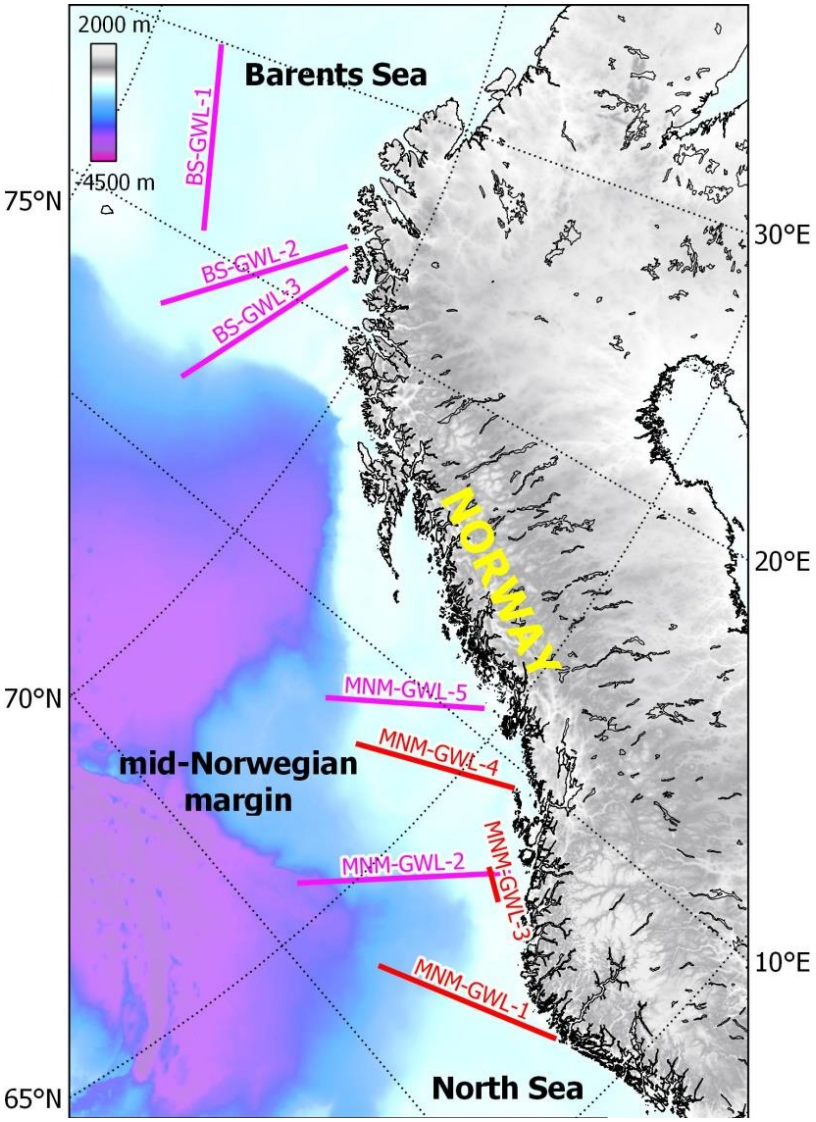
**MNM-GWL-2 & MNM-GWL-3:** aim to **better constrain the highly magnetic and elevated basement of the Frøya High** and its borders including the deep basins expected to the southwest towards the Jan Mayen Corridor in between the Møre and Vøring Basins and northeast towards the southern Halten Terrace. **The Frøya High region shows a lack of deep relevant seismic data and the origin and nature of the deep crust is unclear.** Mapping the nature of the sediments and crust underneath the deep base Cretaceous unconformity will provide further insight into the controversial necking zone up to the central crustal rafts observed in the central part of the corridor (e.g. Slettringen Ridge).




# Geological Context

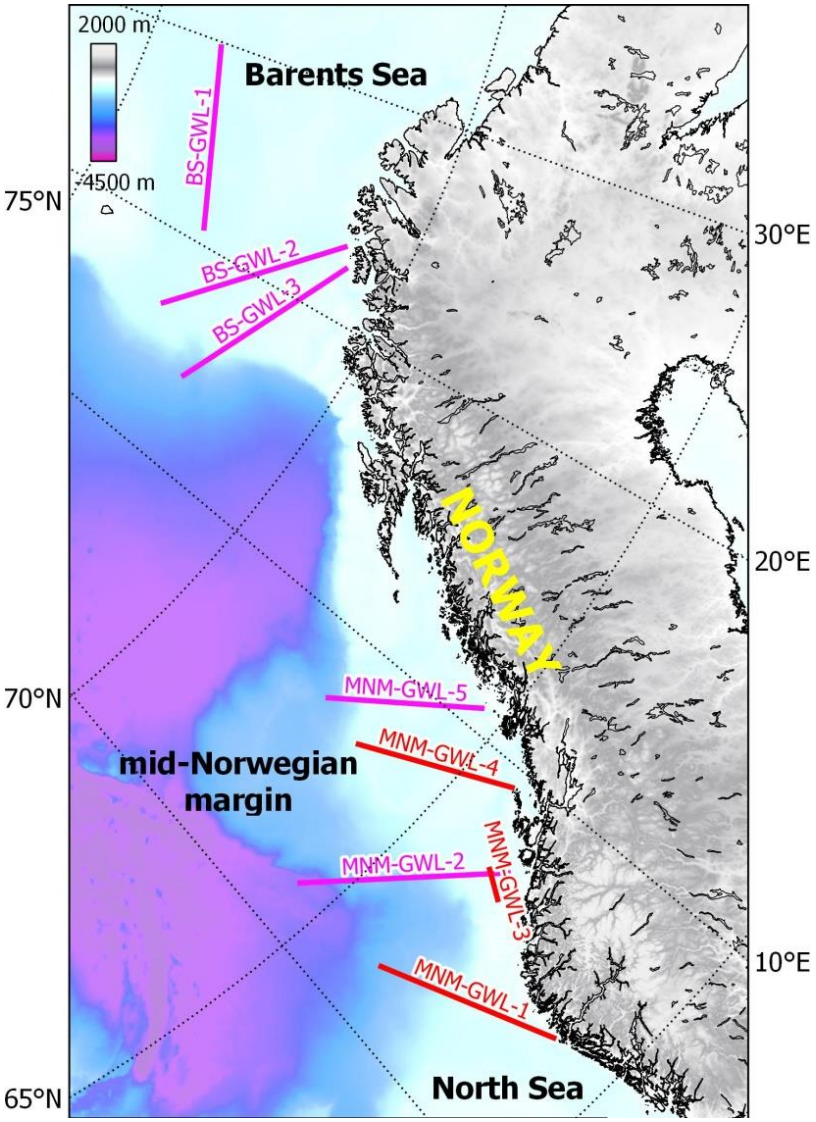
**MNM-GWL-4:** will better constrain the magnetic basement observed between the Froan Basin and the Trøndelag Platform, an area not well covered by the existing refraction seismic lines. To the west MNM-GWL-4 will also constrain the southern part of the Nordland Ridge and the deep part of the Dønna Terrace.

**MNM-GWL-5:** was specially chosen to image better the basement and deeper structures between the Helgeland Basin and the central Nordland Ridge. To the west, we expect to image better the Utgard High and the deep Træna Basin, where drastic thinning of the crust and possible exhumation of the lower crust directly underneath the deep sediments is expected.



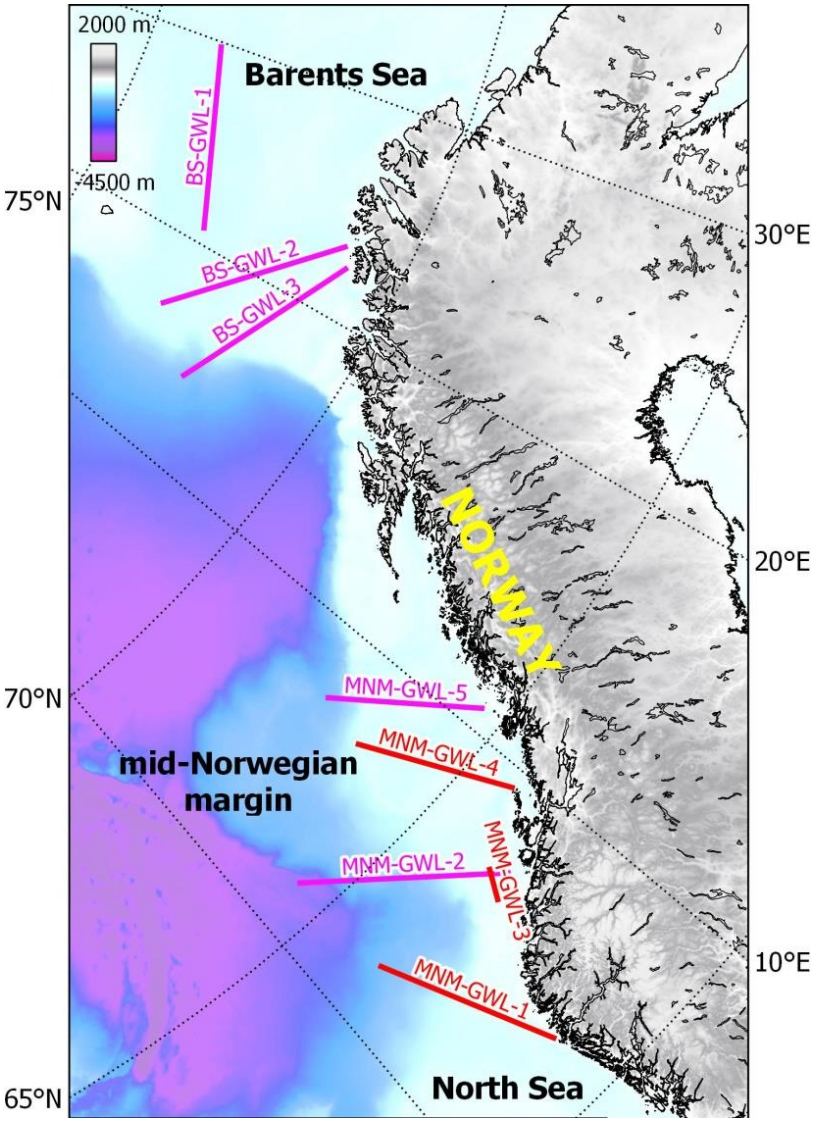

# Geological Context

**BS-GWL-1:** in the Barents Sea is chosen along one of the most recent NBR seismic lines. The transect is selected to **illustrate the entire basement history** of the BS from the Caledonian Middle Allochthons Front expected at the edge of the prominent NW-SE magnetic anomalies in the Bjarmaland Platform to the continent ocean transition further south. We aim to **image the expected deep** NW-SE-oriented **Late Palaeozoic basins** and resolve its connection to the oblique trending Mercurius High. BS-GWL-1 also crosses over the Svalis Dome area, where **imaging of the sub-salt sequences and underlying basement is intended**. The profile will also cross the northernmost part of the Loppa High.




# Geological Context

**BS-GWL-2:** extends from the Seiland Igneous province onshore up to the Bjørnøya Basin. The **section crosses over the Gohta High and the Veslemøy High between the Tromsø and Bjørnøya Basin**. Both highs are a characterised by anomalous upper basement but their meaning remains unclear. BS-GWL-2 will also **constrain better the deep structure of the Hammerfest Basin**. Surprisingly, no refraction data cover this important Mesozoic Basin of the BS and the nature and/or depth to the basement is still speculative from the platform to the deep graben.




# Geological Context

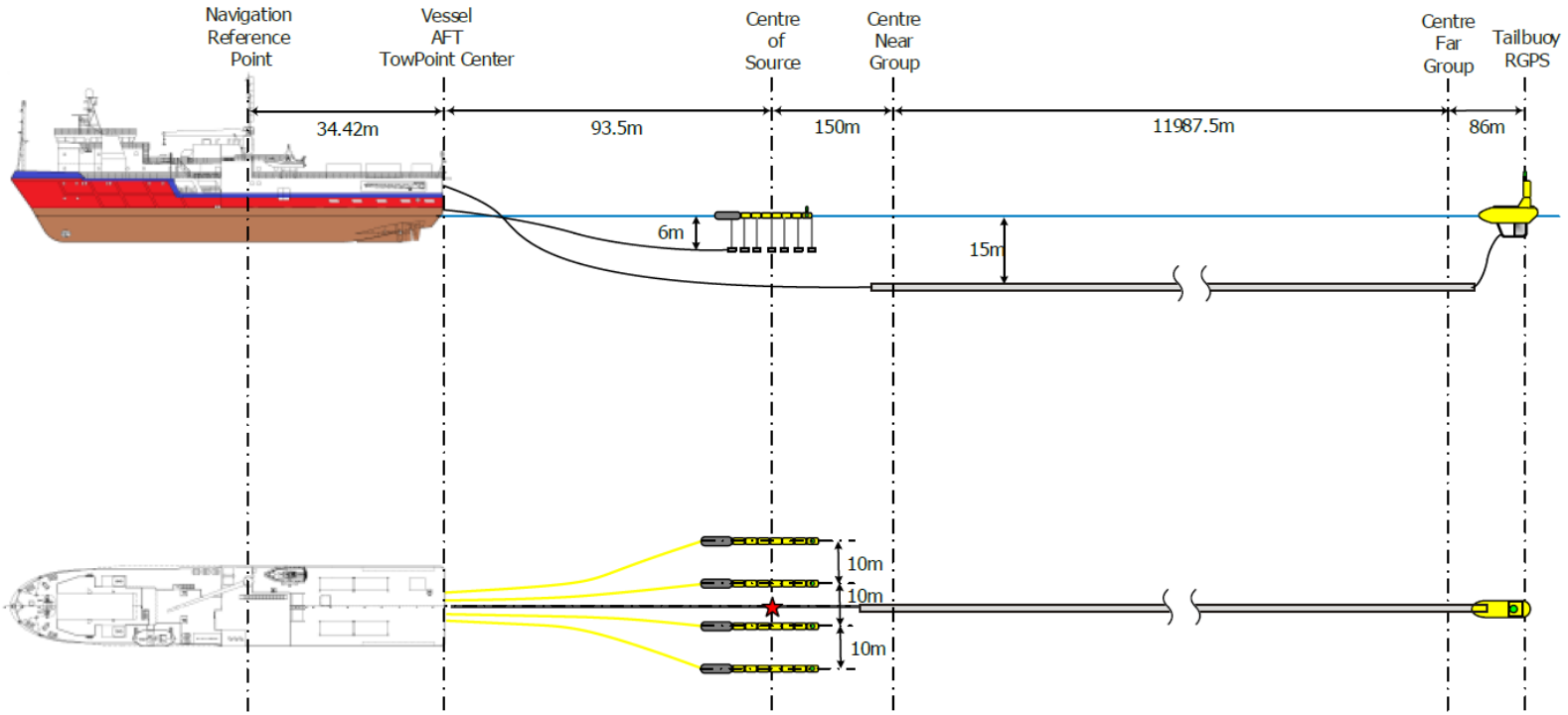
**BS-GWL-3:** plans to **constrain a large part of the sheared margin between the Finnmark Platform and the Norwegian-Greenland Sea**. We aim to understand better the meaning of the necking zone between the Hammerfest Basin and the deep Tromsø Basin, where a drastic thinning of the crust is also expected. Here, **imaging underneath local salt domes** also represents a challenging thematic. BS-GWL-3 will also cover the enigmatic Senja Ridge. The southwestern termination of the profile will also cover the continent-ocean transition in deepest part of the Sørvestnaget Basin.

# Acquisition Parameters

| | Conventional streamer seismic | FloatSeis™ |
|---|---|---|
| Source | 6100 cu in, 2000 psi | 4880 cu in, 2000 psi |
| Shot Point Interval | 50 m | 150 m |
| Gun depth | 10 m +/-1 m | 25 m +/-1 m |
| Streamer Length | 12000 m | N/A |
| Fold | 120 at 6.25 m CMP interval | N/A |
| GWL Seismobuoy™ spacing | N/A | 3 km |
| FloatSeis™ maximum recorded offset | N/A | 60-90 km |

SeaBird Exploration

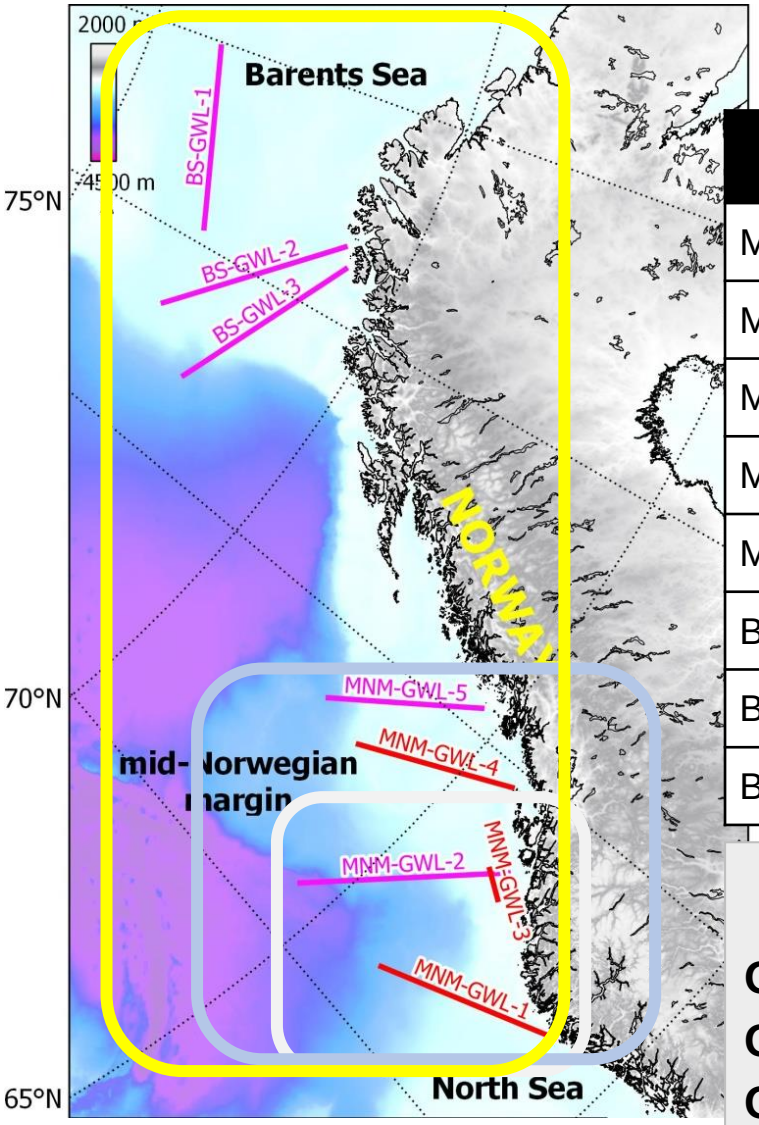
# Seismic Streamer Vessel




| | | | |
|---|---|---|---|
| Gross tonnage: | 3072 t | Streamer Length: | 12 km |
| L.O.A: | 76 m | Receiver point interval | 12,5 m |
| Width: | 14 m | Streamer depth: | 15 m |
| Draught: | 5,2 m | Gun depth: | 10 m |
| MGO consumption: | 14 $m^3$/day | Source volume: | 6100 cu. in. |

# FloatSeis™ Vessel


**Type of Vessel**: Chase/Support
**Gross tonnage:** 387 t
**Overall Length**: 37 m
**Draft**: 4.2m
**MGO consumption**: 4 $m^3$/day




# Project's Options:

| Line | Option1 (Ivory) | Option2 (Silver) | Option3 (Gold) |
|---|---|---|---|
| MNM-GWL-1 | + | + | + |
| MNM-GWL-2 | + | + | + |
| MNM-GWL-3 | + | + | + |
| MNM-GWL-4 | | + | + |
| MNM-GWL-5 | | + | + |
| BS-GWL-1 | | | + |
| BS-GWL-2 | | | + |
| BS-GWL-3 | | | + |

**Price for early participants:** 200.000 USD

**Option 1:** Total volume 650 km – 4 participants;
**Option 2:** Total volume 1150 km – 6 participants;
**Option 3:** Total volume 2000 km – 8 participants;

# Project Time Schedule:

| Work | 2019 | | | | 2020 | | | |
|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q1 | Q2 | Q3 | Q4 |
| FloatSeis™ field acquisition | | X | | | | | | |
| FWI velocity model building | | | X | | | | | |
| Fast-track processing | | | X | | | | | |
| Time processing before migration | | | | X | | | | |
| PSTM | | | | X | | | | |
| PSDM | | | | X | | | | |
| PSDM with FWI velocity models | | | | X | | | | |
| 2D gravity & magnetic modelling and interpretation of data | | | | | X | X | | |
| Final report | | | | | | X | | |

**Starting date:** May 2019
**Completion date:** June 2020
**Project duration:** 1 year

# Business Model:

Project **participants are co-funding** the pilot fieldwork.

GWL and NGU are joint applicants with GWL leading the project.

**GWL and NGU consider this academic project as a non-profit. Funds will be used to cover project costs only.**

The final scope of the project will depend on the amount of raised funds.

All the **data** obtained by this project will be **jointly owned by participants**, including GWL. **GWL does not claim the right to license the data to third parties**, but use it for research and publication.

The results of the seismic profiles are sensitive for GWL in connection to its intellectual property. GWL limits technological/seismic company's participation in the project (direct competition) and also limits the rights to transfer the results to such companies without coordination with GWL.

All rights to the technology development as well as equipment exclusively belong to GWL. This project does not transfer any part of the rights to the technology and equipment to the project participants.

# Project Team

Mr. Aleksandr Nikitin,
COO, GWL

Dr. Laurent Gernigon,
Senior Researcher, NGU

Mr. Nikolay Amelin,
CEO, GWL

Dr. Sofie Gradmann,
Senior Researcher, NGU

# When deep means Ultra-Deep

## Deliverables:

- RAW field data (Ultra-deep streamer data + Ultra-long offset GWL Seismobuoy™ SEG-Y records) + Navigation P1/90;
- PSDM, PSTM gathers, SEG-Y;
- FWI velocity models and PSDM with FWI velocity models, SEG-Y
- 2D gravity and magnetic modelling based on PSDM velocity models;
- Geological and tectonic interpretation;
- Final report

# Thank you for your attention

For more information, please contact:
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