Use of high-resolution 3D marine seismic for offshore CCS characterization and monitoring

Update on deployment at Tomakomai August 2017

GCCC GULF COAST CARBON CENTER

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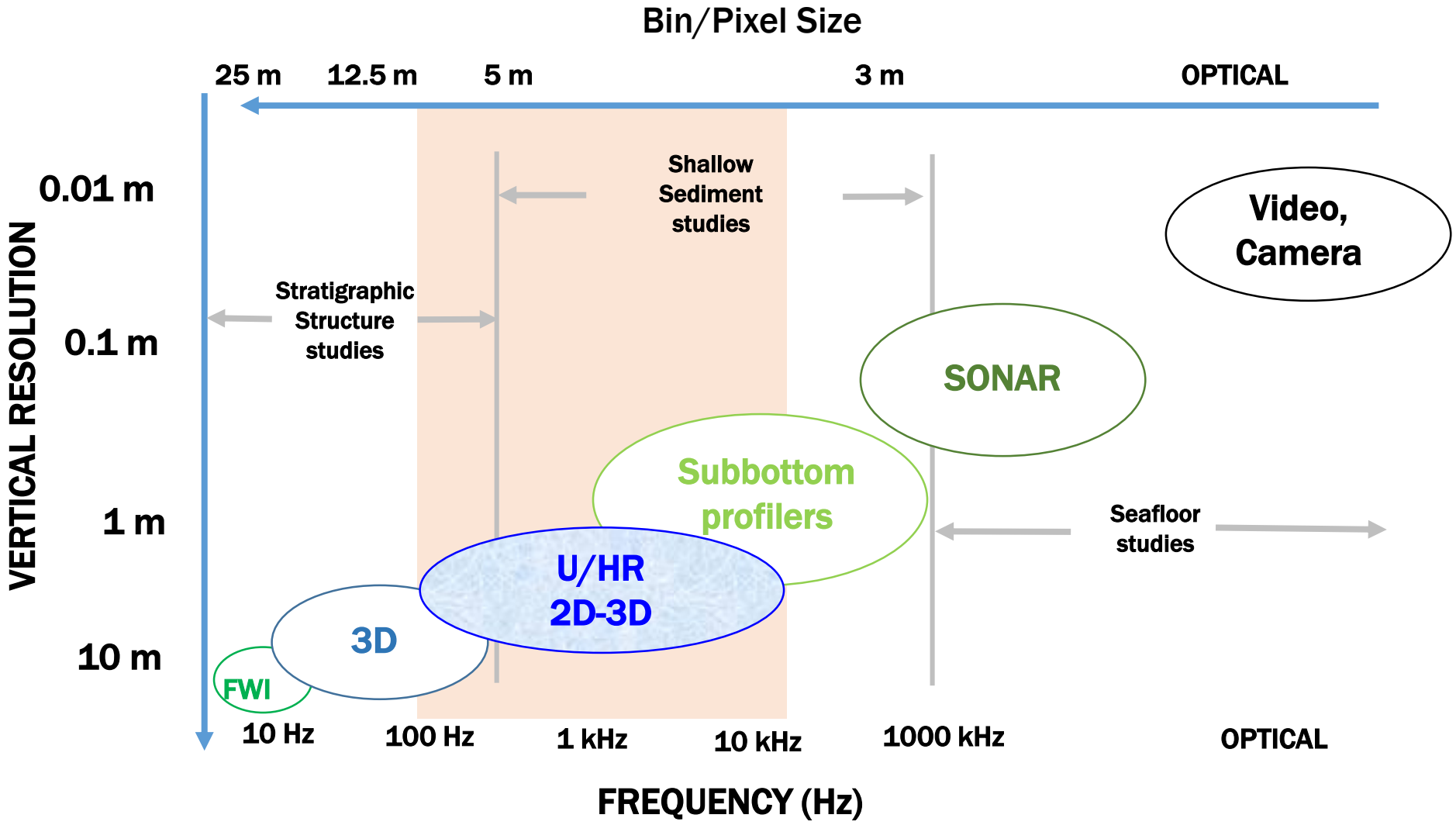
uHR3D Niche



Modified from Hill et al., 2015, Leading Edge

Conventional 3D

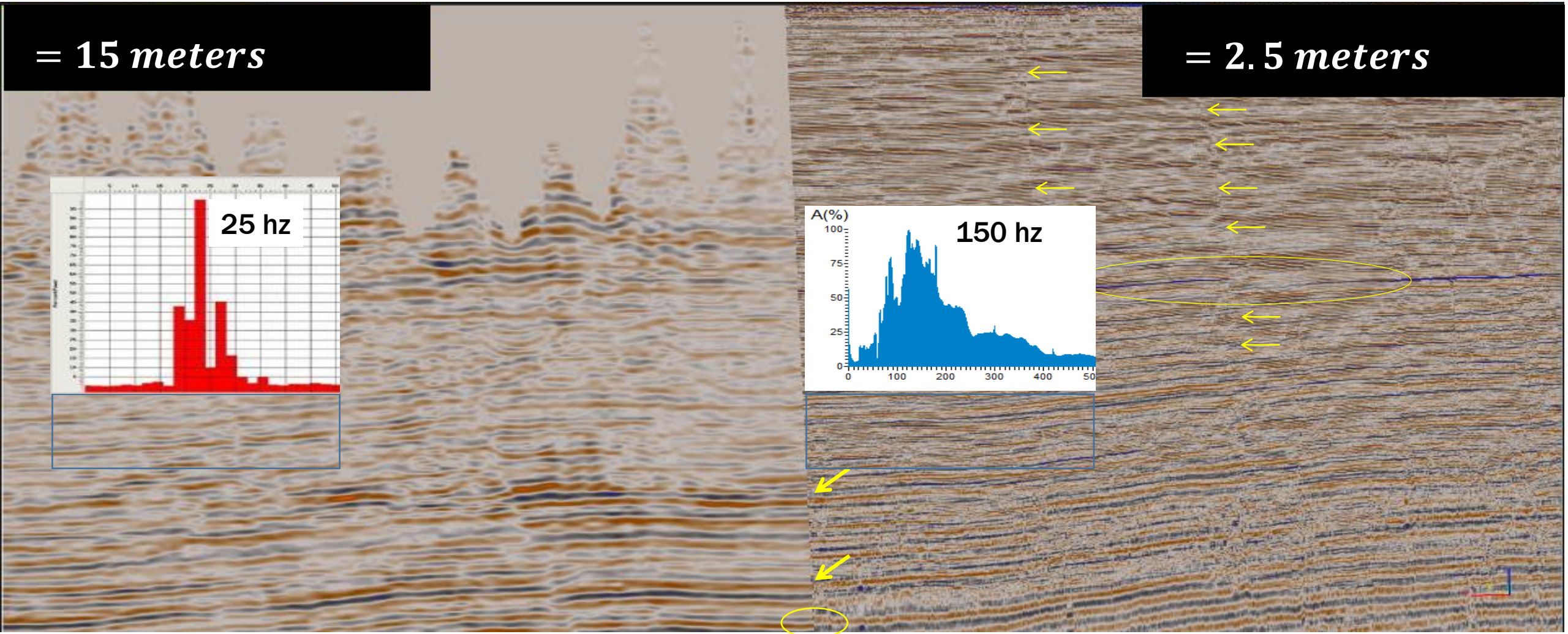
$$= \left(\frac{1}{25\ hz} * 1500\ m/s\right)/4$$

Vertical Resolution

$$= \left(\frac{1}{f} * V\right)/4$$

HR3D - PCable

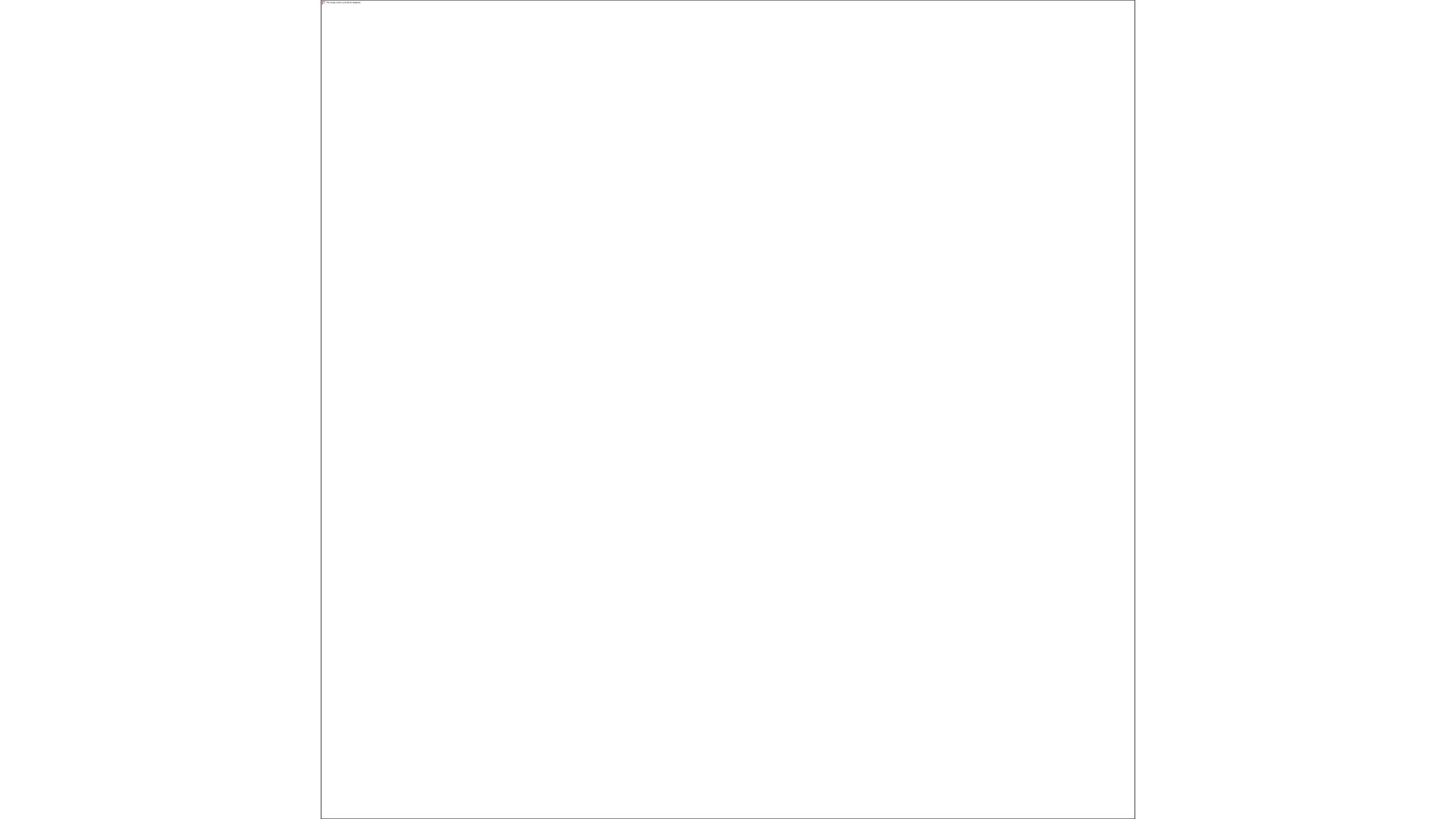
$$= \left(\frac{1}{150\ hz} * 1500\ m/s\right)/4$$



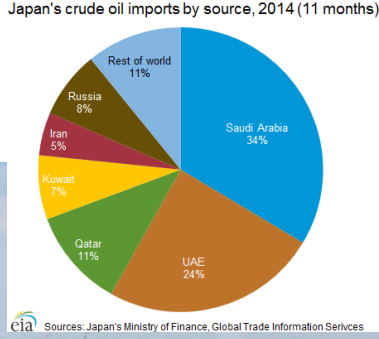
Existing conventional 3D

1500 ms ~ 1125 meters depth

2012 UT Pcable HR3D

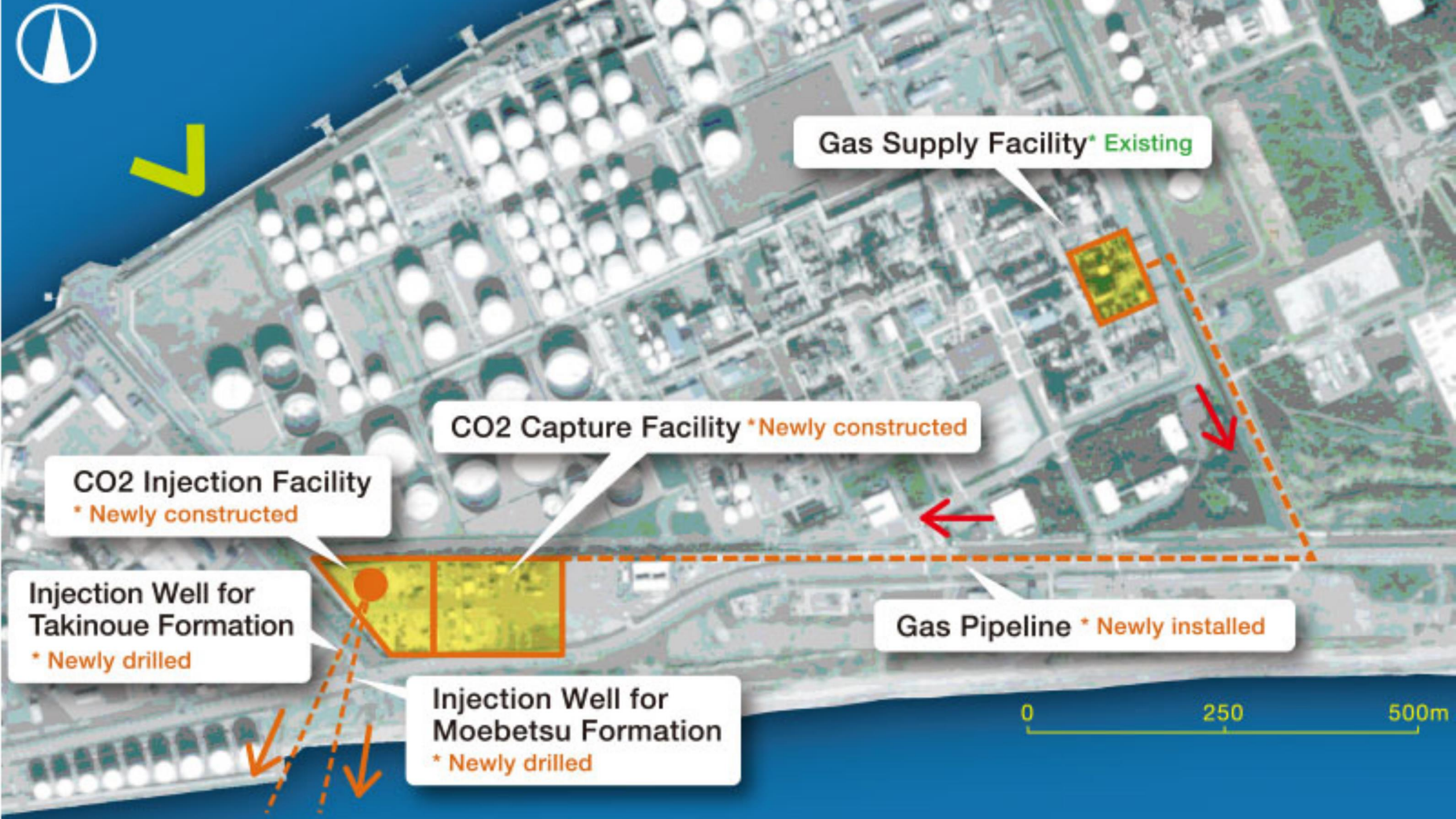


~4 MMBO imported/day

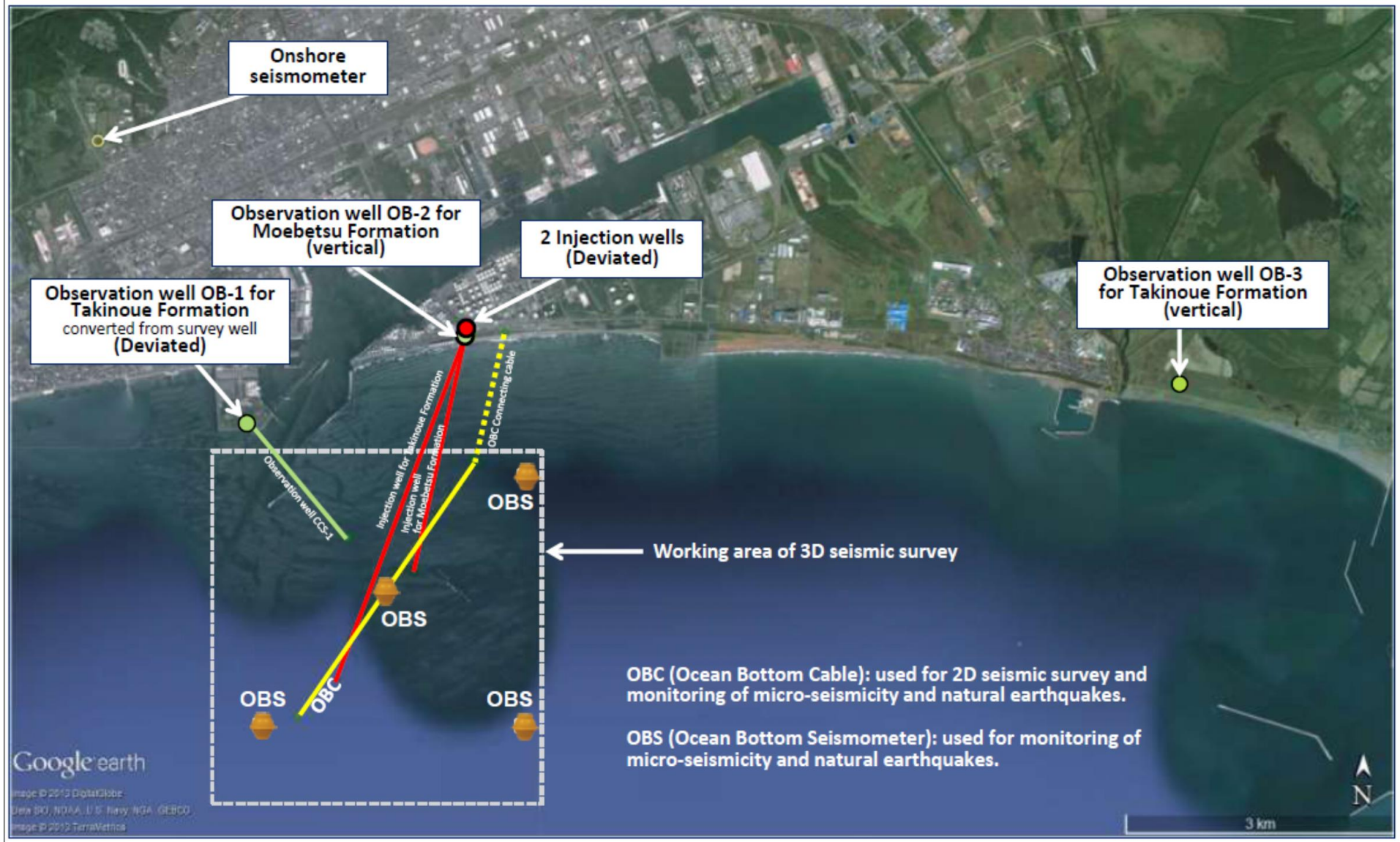


CO_2 Project Basics

- Ministry of Economy, Trade and Industry (METI)
- Japan CCS Co., Ltd. (JCCS)
- 2012-2020
- Demonstrate and verify the total CCS system, from CO_2 GAS COMPRESSION & CO_2 CAPTURE to storage
- 100,000 tonnes/year
  - CO_2 is captured from offgas generated at a hydrogen production unit in the adjacent refinery plant
- Two separate reservoirs (saline aquifers) approximately 1100 m and 2400 m
- 2 INJ; 3 OBS
- Marine 3D seismic surveys were conducted in 2009 and 2010, and two survey wells were drilled in 2011.
- 2 reports to METI; “Geological evaluation report of Tomakomai Area”, and “Basic Plan of CCS demonstration project at Tomakomai Area”

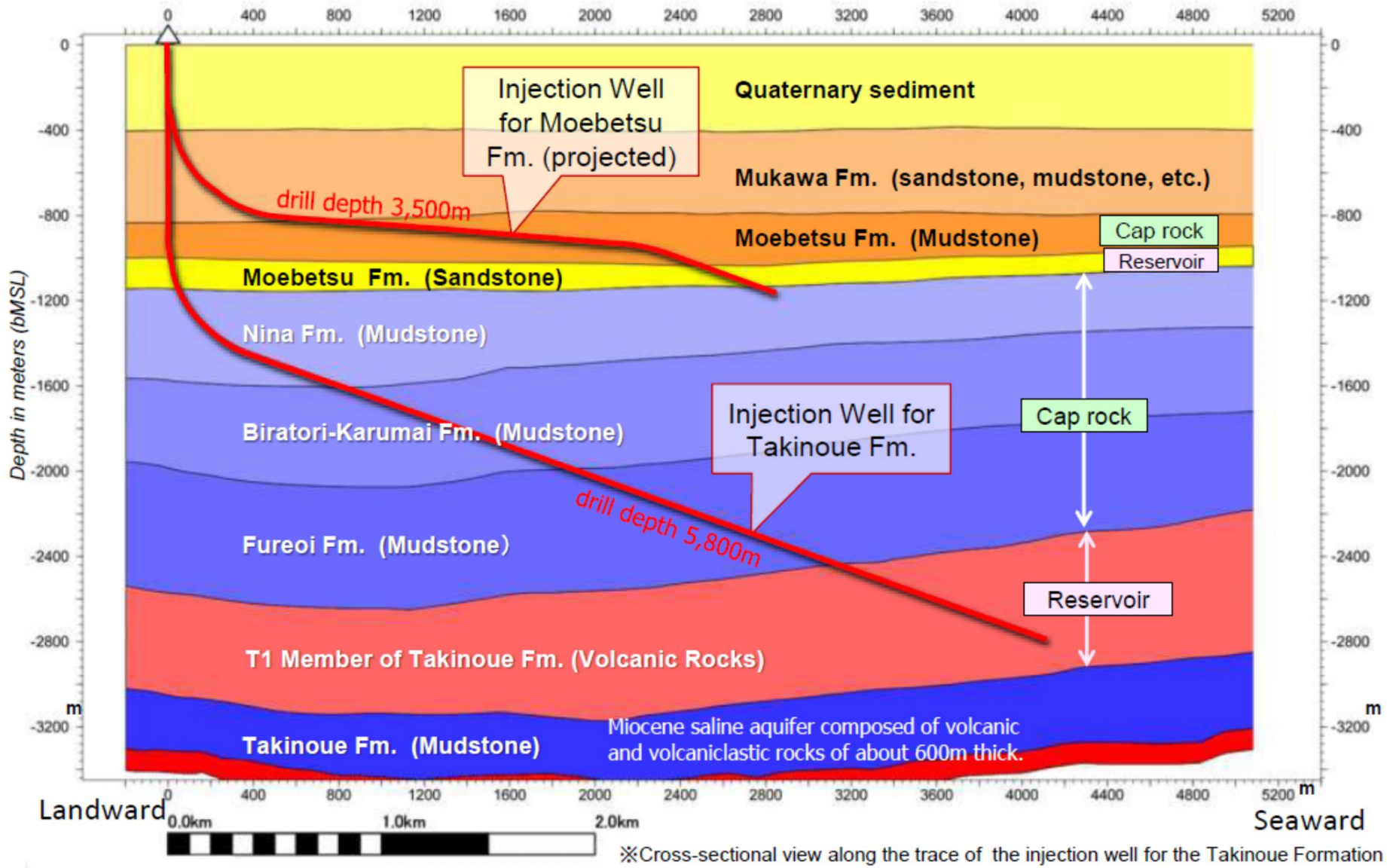

Gas Supply Facility* Existing
CO2 Capture Facility *Newly constructed
CO2 Injection Facility
* Newly constructed
Injection Well for
Takinoue Formation
* Newly drilled
Injection Well for
Moebetsu Formation
* Newly drilled
Gas Pipeline * Newly installed
0
250
500m

Layout of Monitoring Facilities



JCCS

Schematic Geological Section



※Cross-sectional view along the trace of the injection well for the Takinoue Formation

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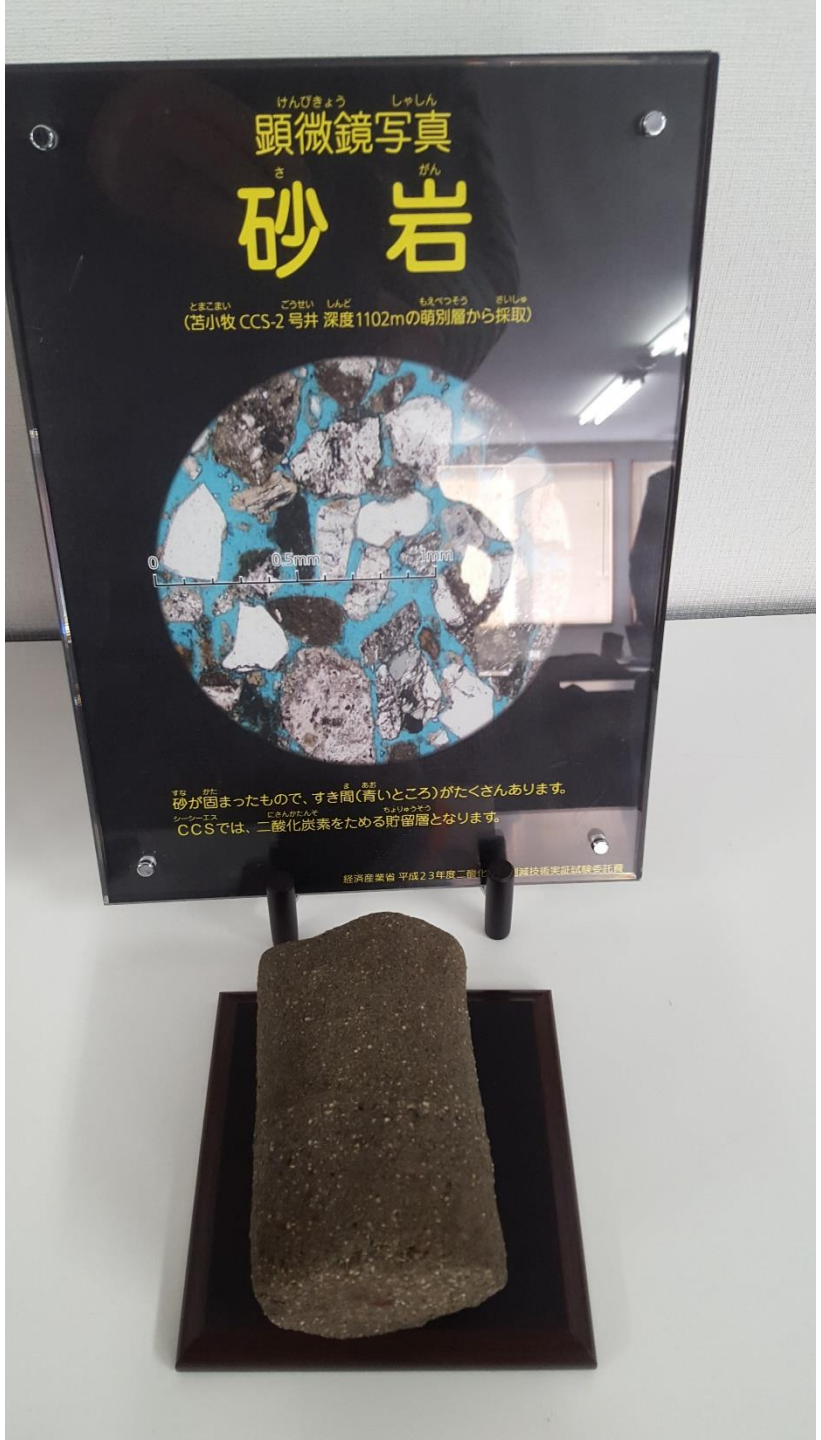
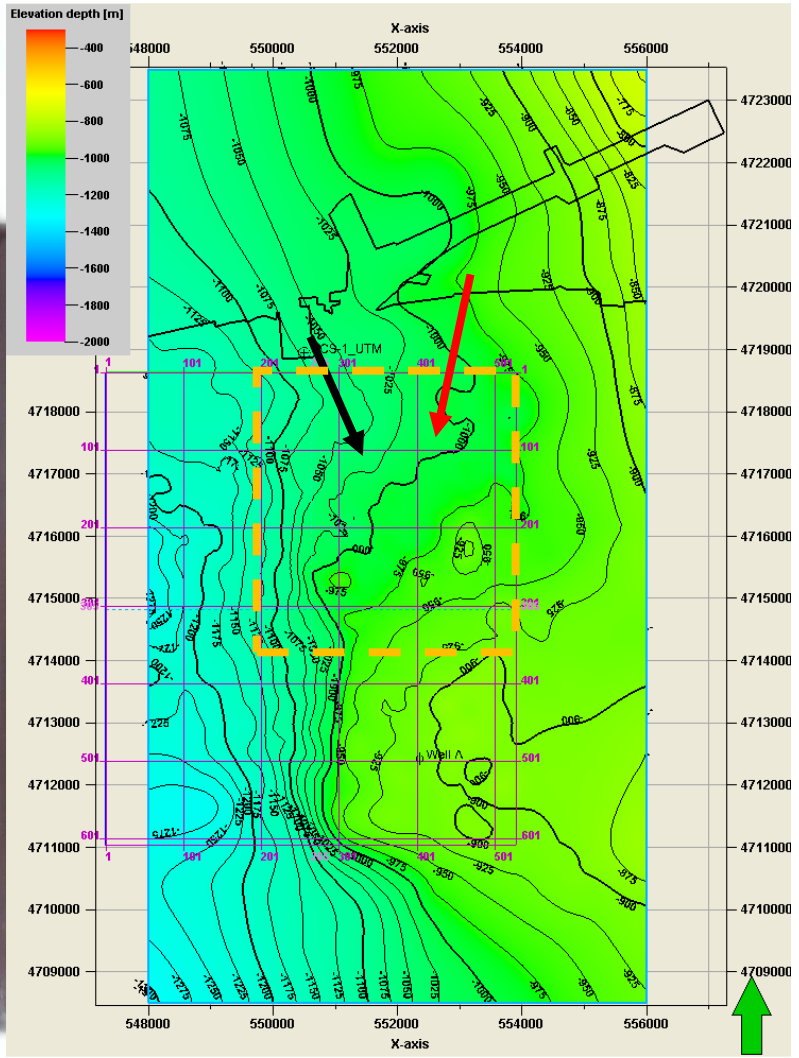
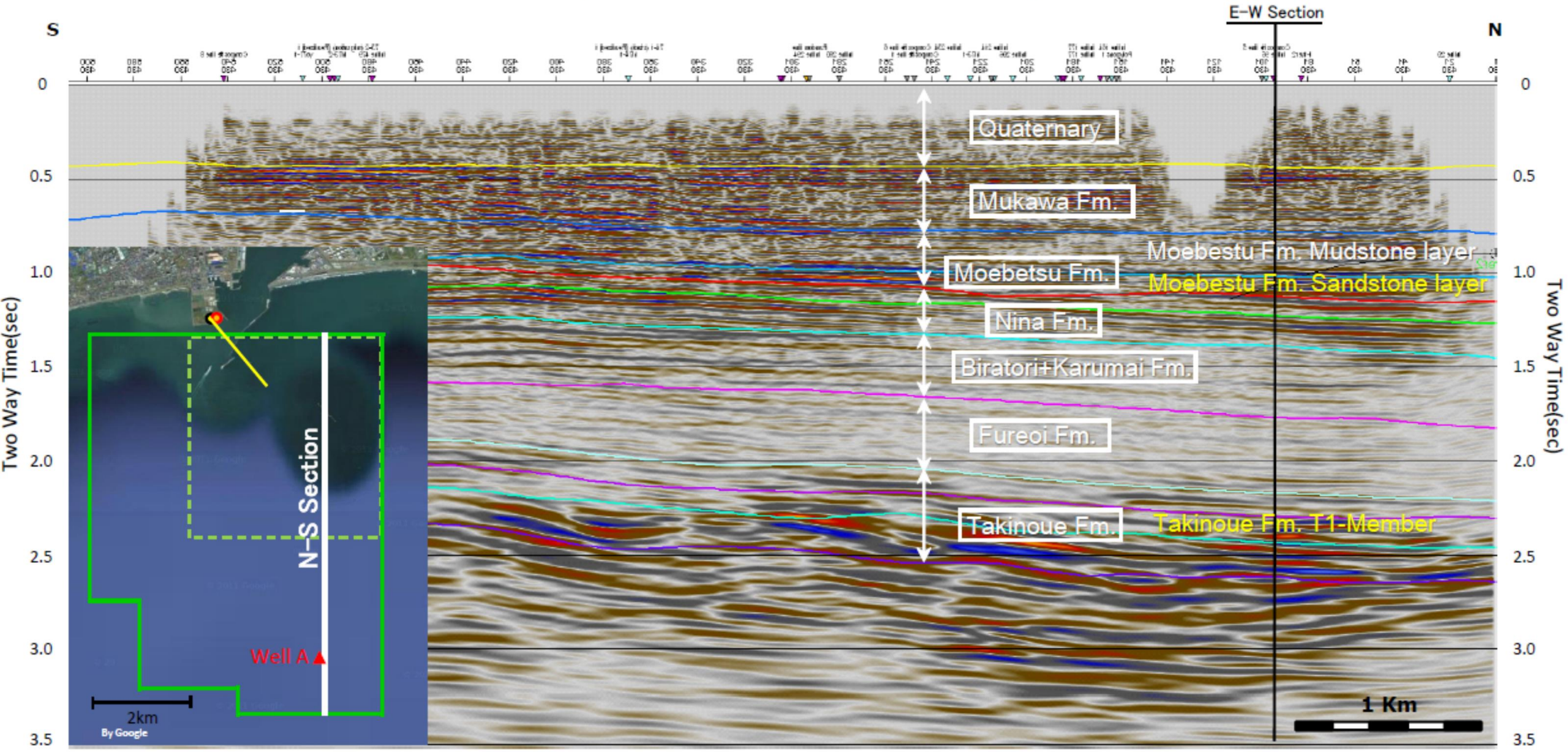


1,100 to 1,200 m deep
20 to 40% and 9 to 25md
gentle monocline structure with 1 to 3 degrees NW dip



Geological Structure: North-South Section by 3 D Seismic Survey



CO_2-Seismic Sensitivity Study

- At the injection interval depth of ~1,100 m, the Moebetsu Formation can be characterized as a **poorly consolidated, low velocity sandstone with high porosity**. These conditions are generally favorable for seismic response related to changes in pore fluids.
- **Gassmann** (1951) theory is used to predict the change in seismic velocities due to change in CO_2 saturation using in-situ rock properties and ambient temperature and pressure.
- Both **acoustic impedance (P impedance) and P-wave velocity decrease with increasing CO_2 saturation in pores** (expected).
- Both **homogeneous and patchy saturation models** are assumed for the mixing of the CO_2 with the existing fluid in the pores, with homogeneous (fine scale) mixing considered more likely and providing a larger seismic response (using Reuss average method) at the scale of seismic wavelengths.

CO_2-Seismic Sensitivity Study

Temperature=44.8 C

Pore Pressure=10.67 MPa

BRINE

2.49 Bulk modulus (Gpa)

1007 Density (kg/m^3)

CO_2

0.0038 Bulk modulus (Gpa)

265 Density (kg/m^3)

RESIDUAL GAS

0.02 Bulk modulus (Gpa)

137 Density (kg/m^3)

Mineral Composition of Moebetsu
(average values from cores over the interval 968m-1079.35m)

Plagioclase: 36% , Bulk modulus = 75.6 GPa

Clay minerals: 34.5%, Bulk modulus = 25 GPa

Quartz: 23%, Bulk modulus = 37 GPa

K feldspar 6.5%, Bulk modulus = 37.5 GPa

Bulk modulus of the mixture = 40.9 GPa

(Hashin Strikman bounds)

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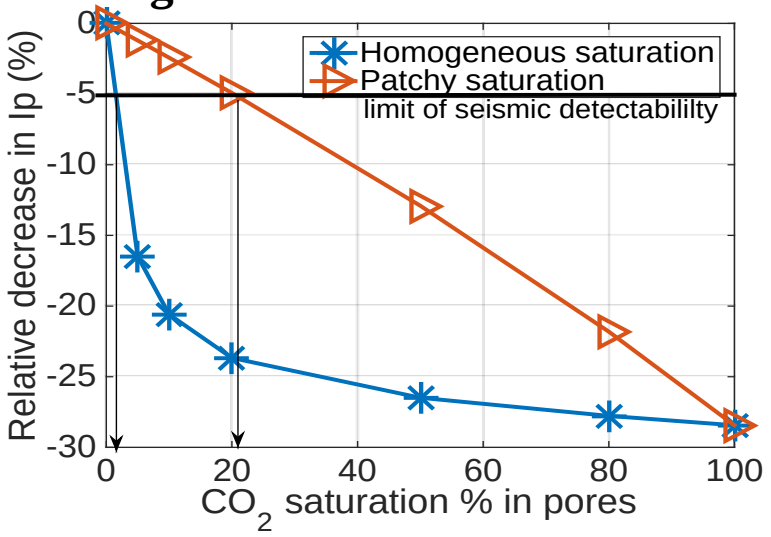
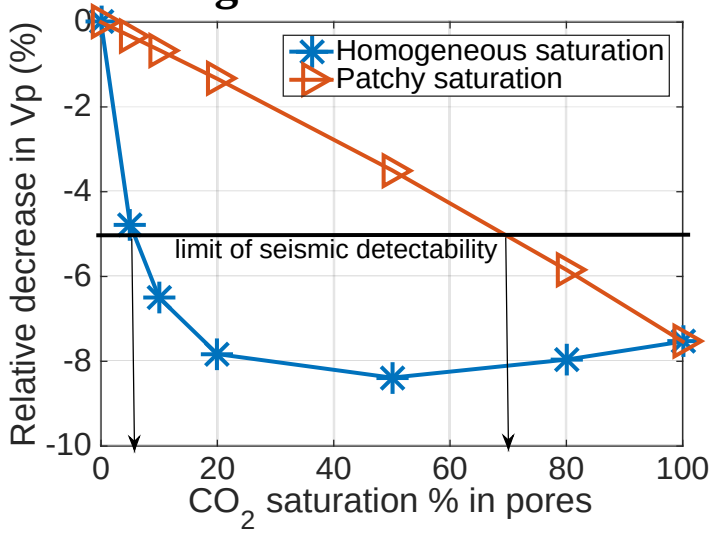
CO_2-Seismic Sensitivity Study

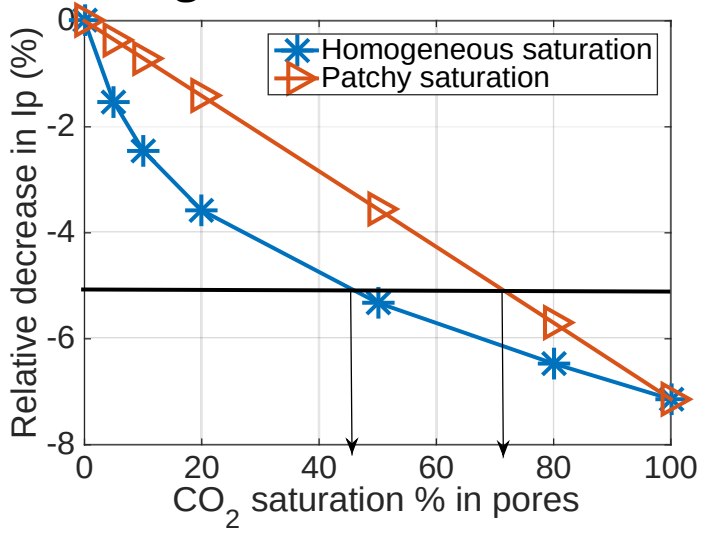
Residual gas saturation is set to 0.5%.



Residual gas saturation is set to 2%.



Residual gas saturation is set to 5%.



- In the absence of **residual gas (methane)** and with high-quality seismic data (high signal-to-noise ratio), the presence and distribution of CO_2 should be identifiable in the Moebetsu Formation using seismic methods.

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HR3D Acquisition – August 2017


OCEAN
CRANE

GCCC
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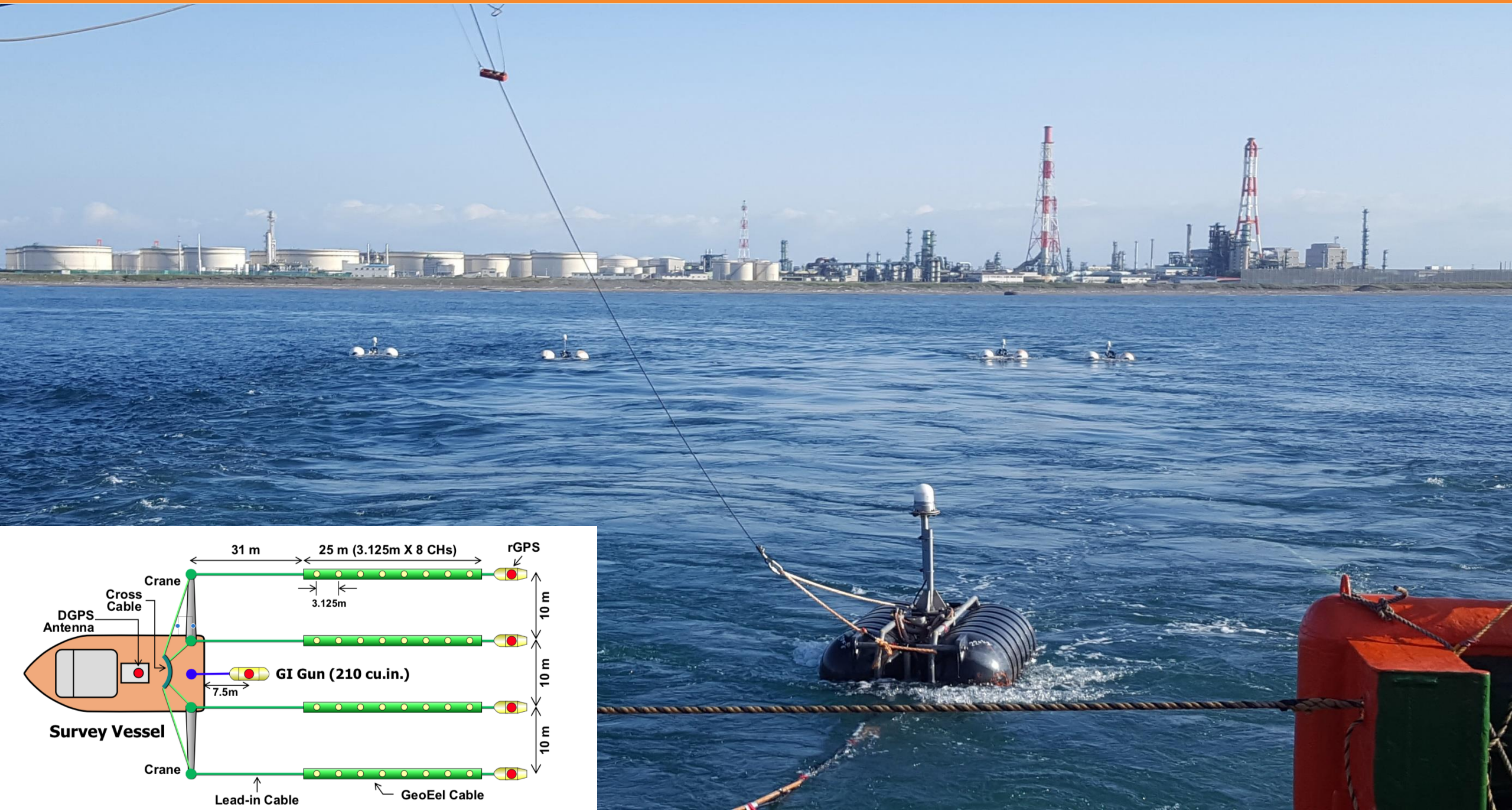
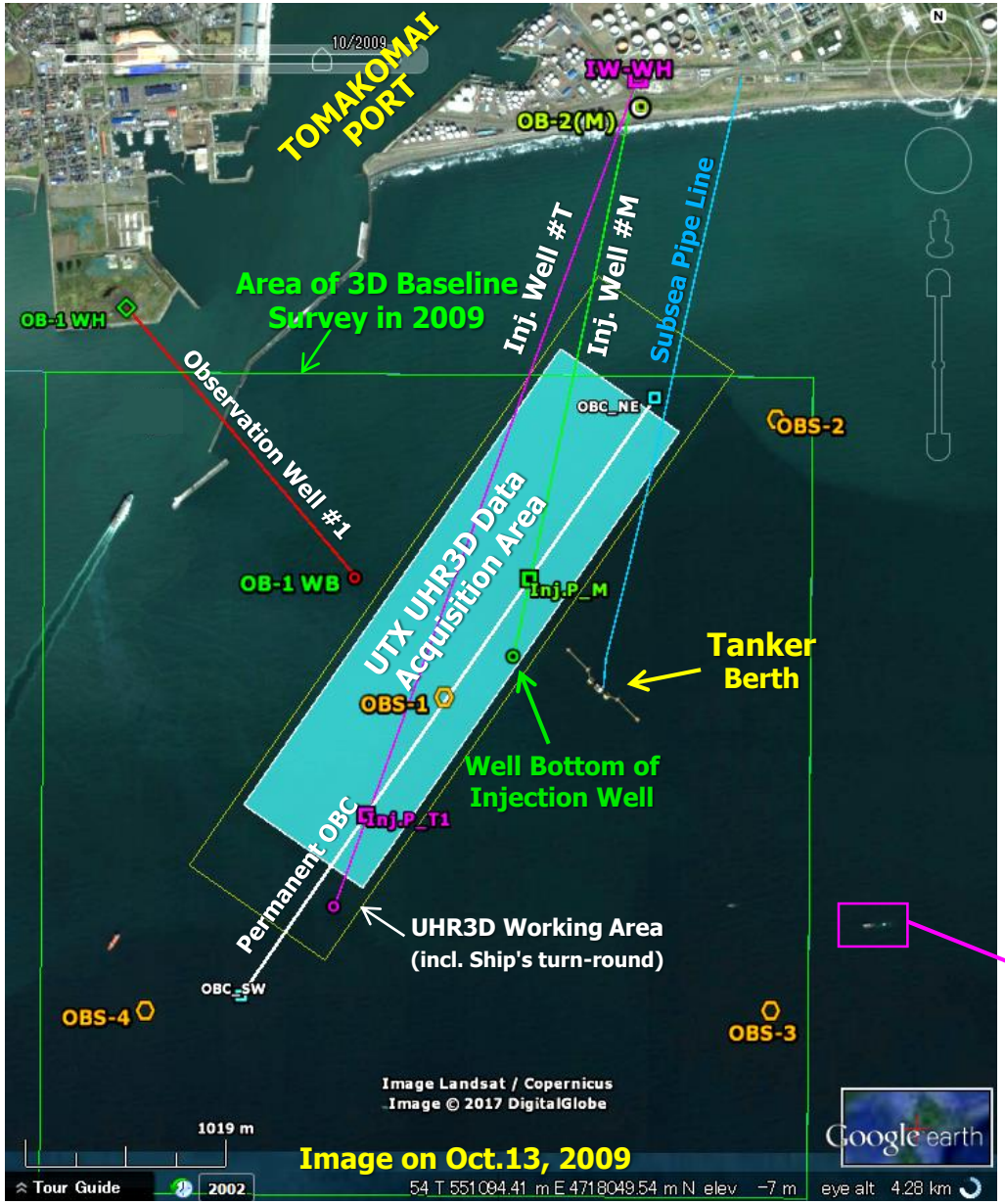
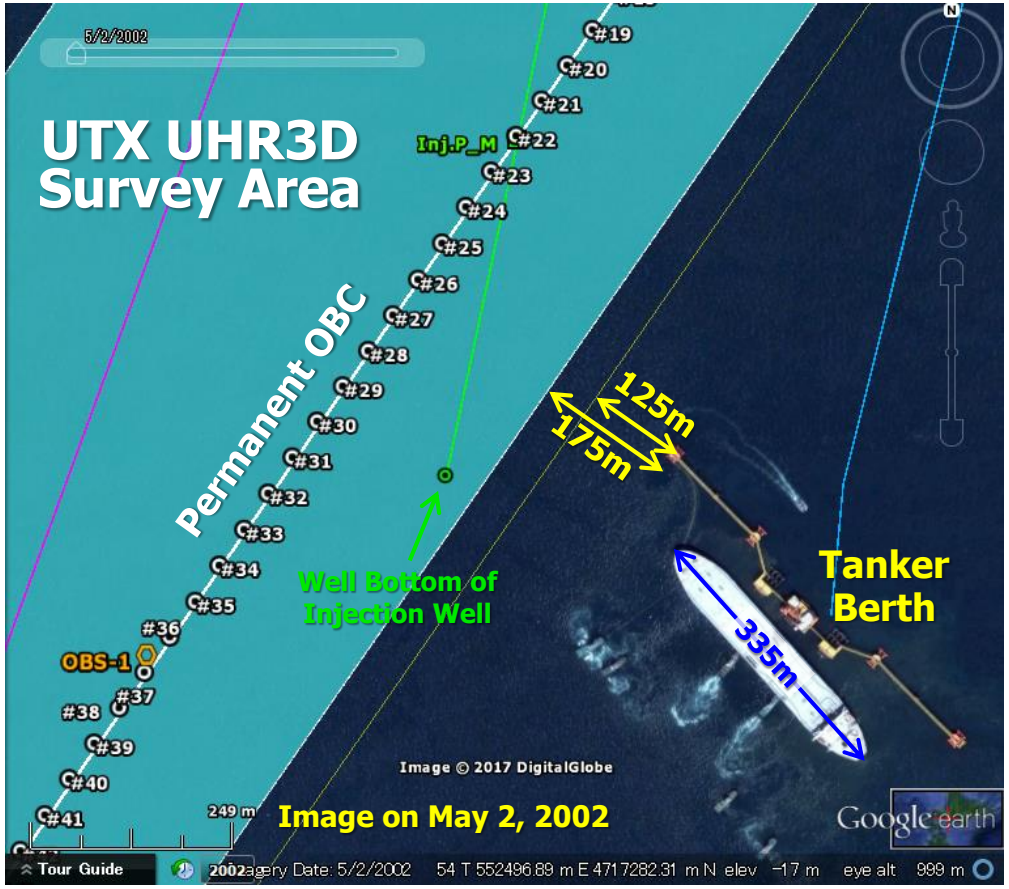

31 m
25 m (3.125m X 8 CHs)
rGPS
Crane
Cross Cable
DGPS Antenna
3.125m
10 m
10 m
10 m
GI Gun (210 cu.in.)
7.5m
Survey Vessel
Crane
Lead-in Cable
GeoEel Cable

Survey Area of UTX UHR3D off Tomakomai (Final Plan)

Rev. 2017.07.21



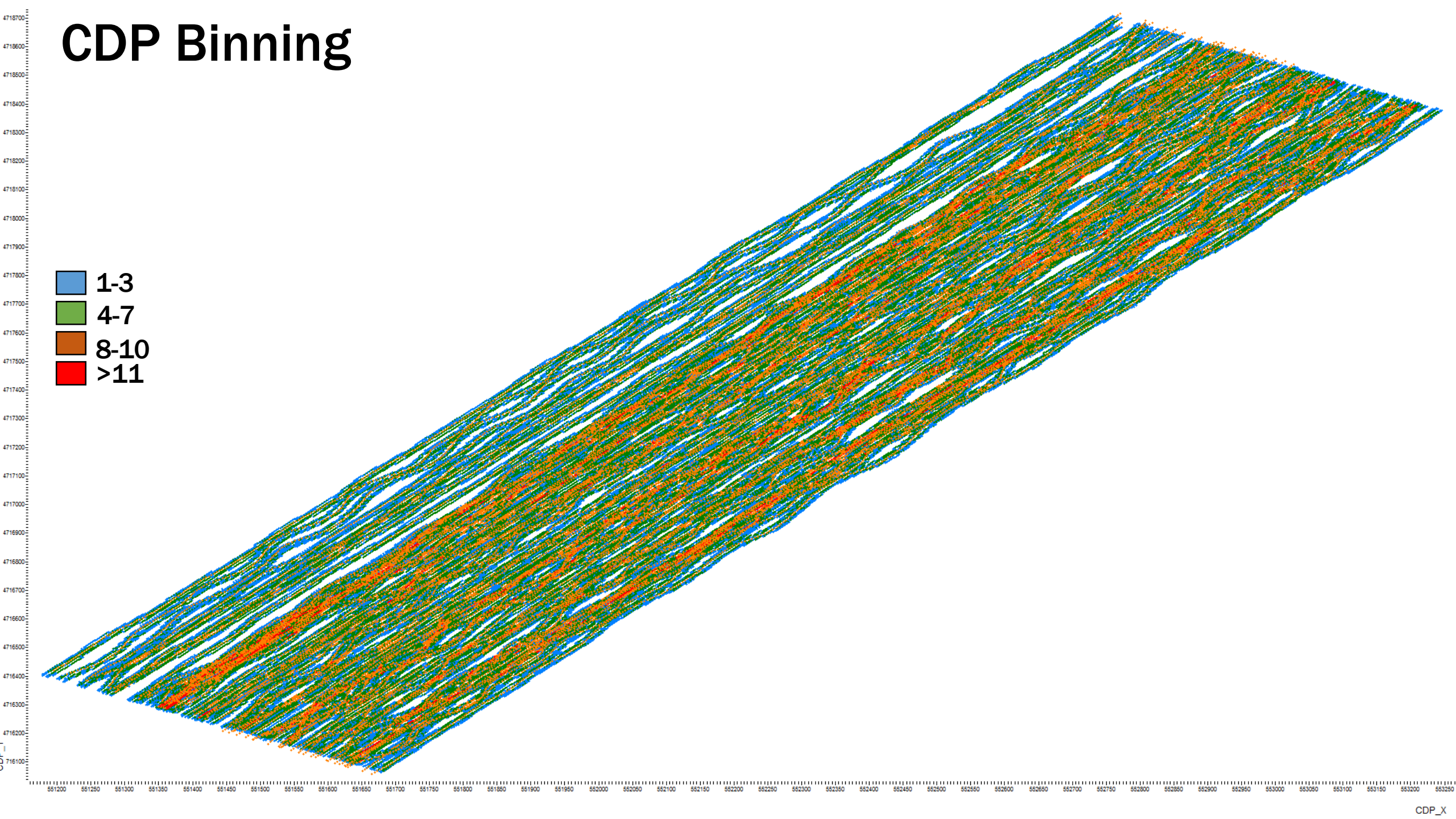


Google Earth Image on Oct.13, 2009 (1st 3D Survey in 2009)

Processing Workflow

1. CDP Binning
2. Deconvolution
   - Minimum Phase Deconvolution (Shot De-signature)
   - Predictive Deconvolution (Short Period multiples and Band Limiting)
3. Spherical Divergence (Gain Recovery)
4. F-K Filtering (Cable Processing)
   - Noise Removal: background noise
   - Noise Removal: linear noises
5. Velocity Analysis (Super Gathers)
6. Stack
7. 5D Interpolation (In progress)
8. Time Migration (TBD)
9. Sub Seismic imaging using Dip Steering (TBD)

CDP Binning

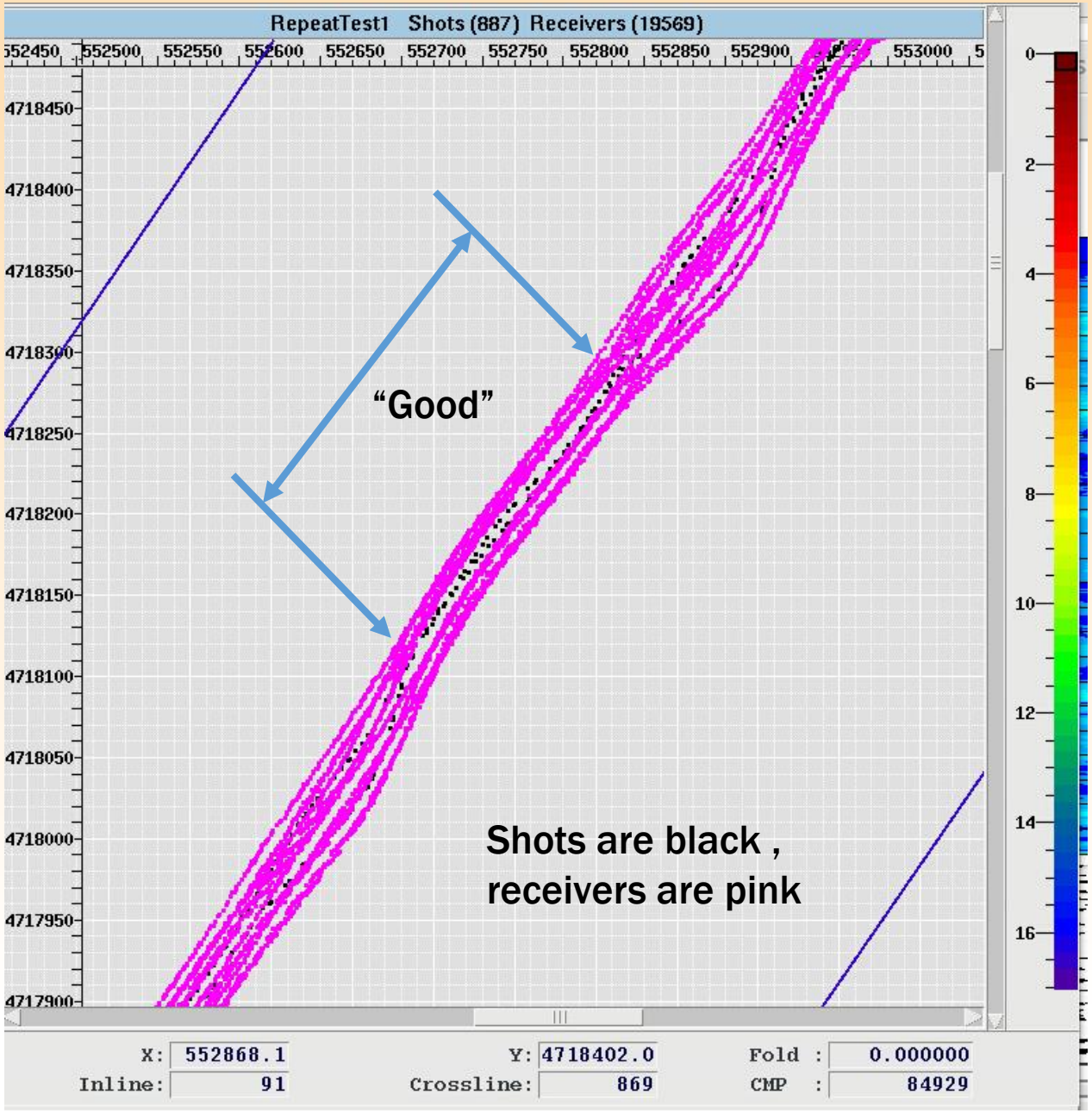


The image cannot currently be displayed.

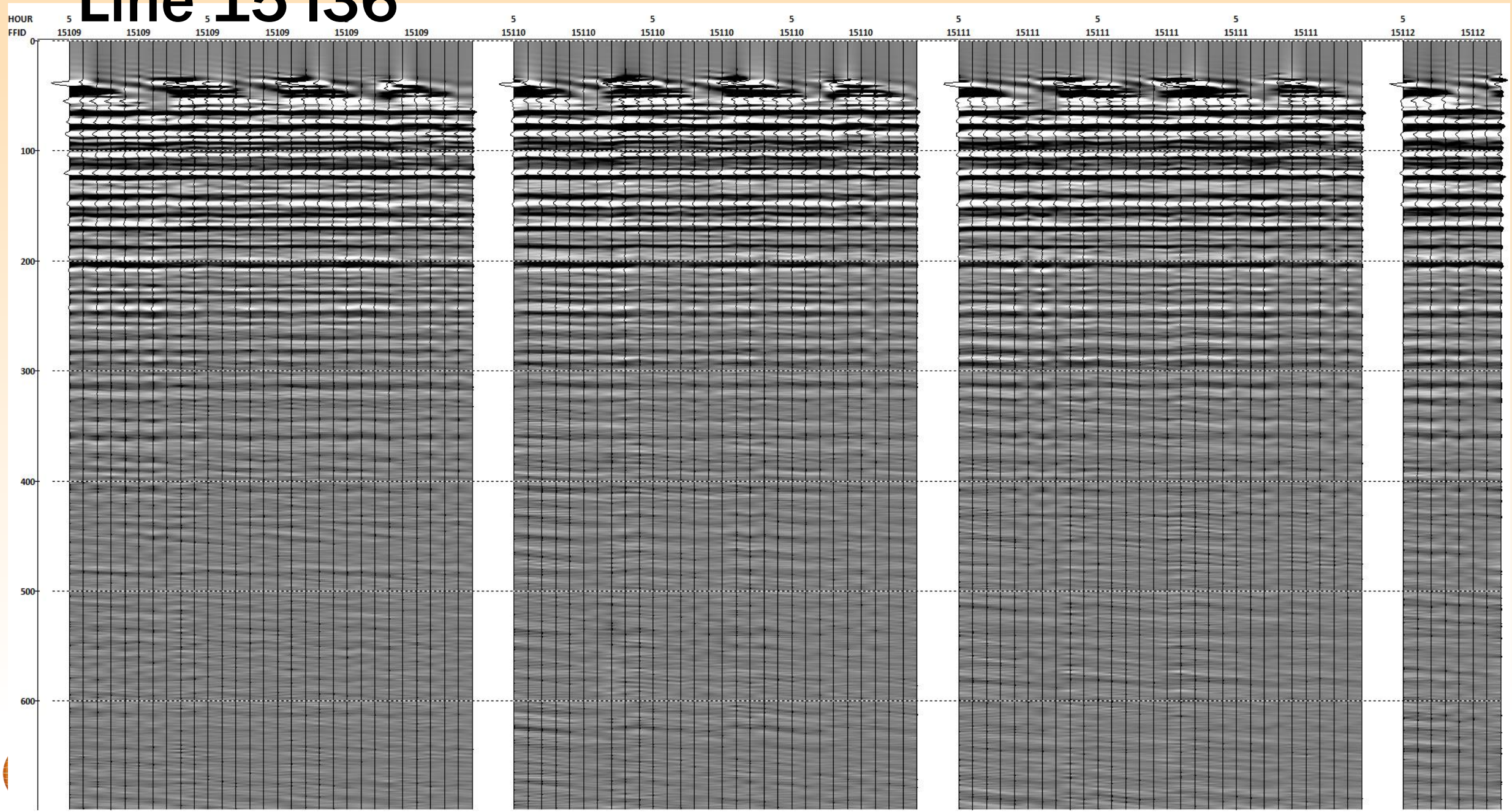
Comparison by Location

Selected data based on location which is shot twice, separated by 3 days 15 hours, same sail line.

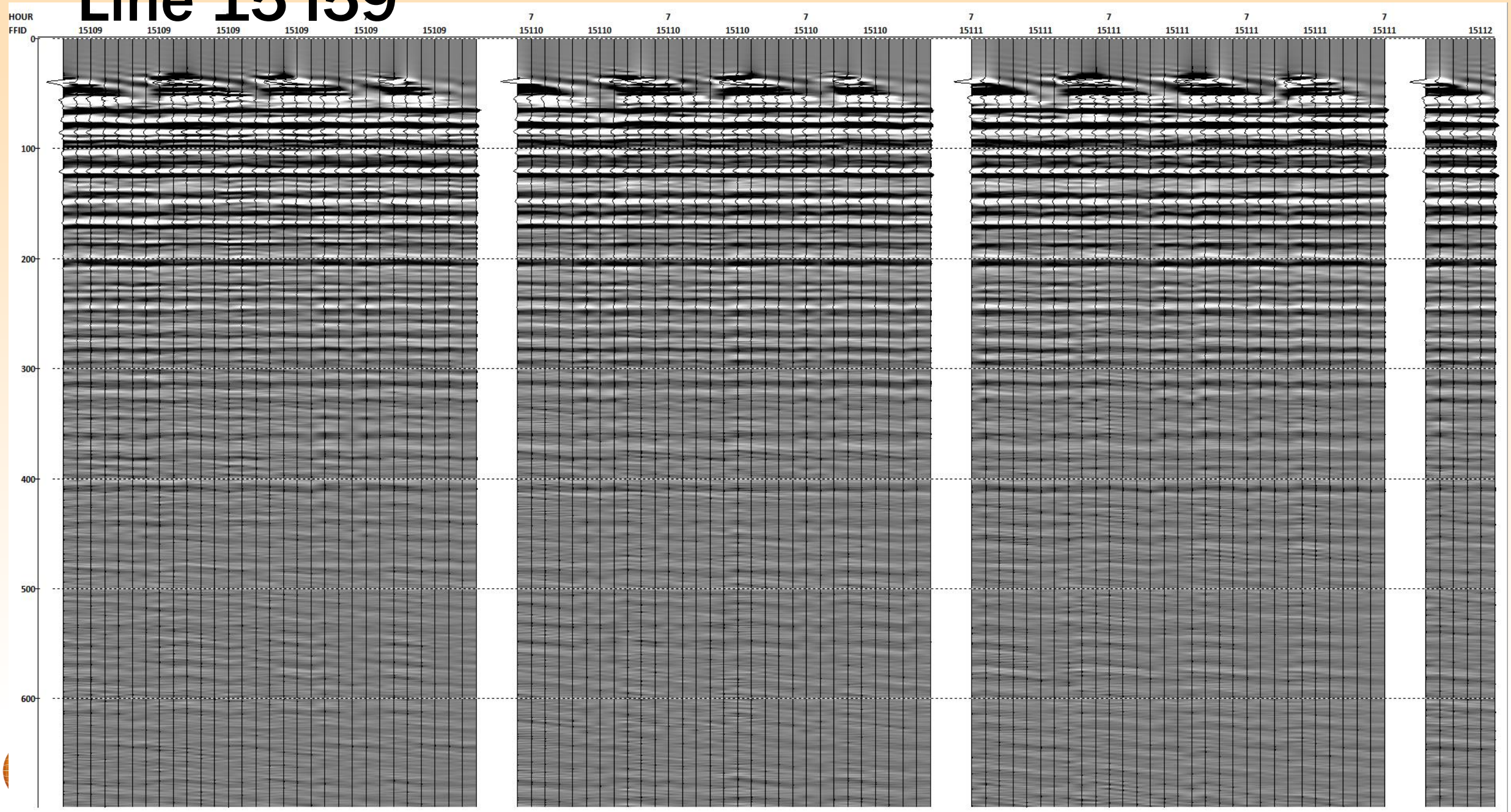
Select area where shot locations and receivers are grouped together (repeatable)



Line 15 I36



Line 15 I59


HOUR
FFID
15109 15109 15109 15109 15109 15109
7 15110 15110 15110 15110 15110 15110
7 15111 15111 15111 15111 15111 15111
7 15112
0
100
200
300
400
500
600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RadExPro 3D Volume Viewer

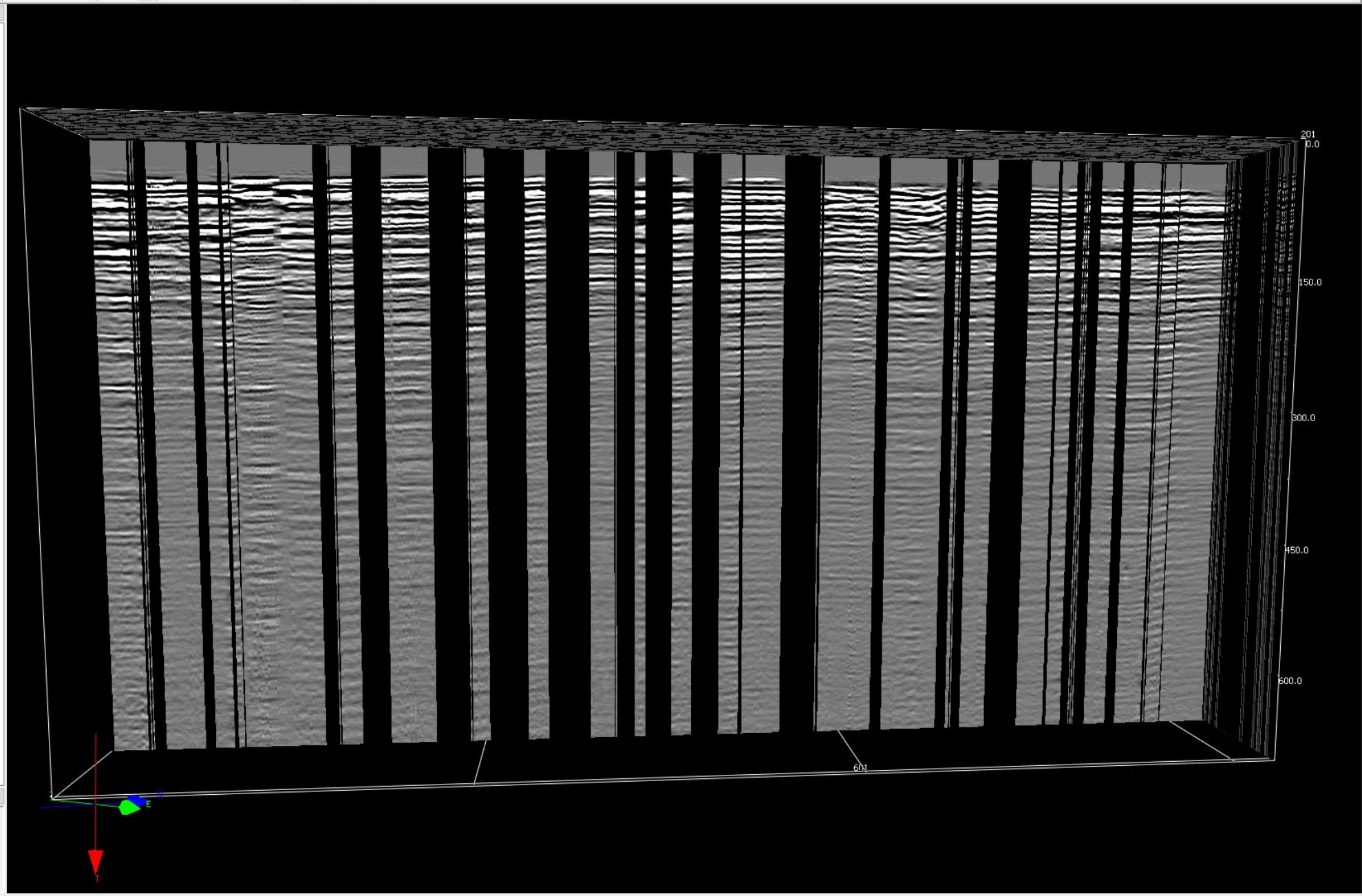
All gains | All biases | Vertical scale: | Data threshold: | All horizons transparency

Objects

- **stack1**
  - inline: 111
  - crossline: 934
  - time: 0.00 ms
- **stack2**
  - inline: 111
  - crossline: 934
  - time: 0.00 ms
- **stack1-2-difference**
  - inline: 106
  - crossline: 468
  - time: 350.00 ms

Slice motion

Step: 1
Velocity: (slices/s) 10.0
invert direction
record



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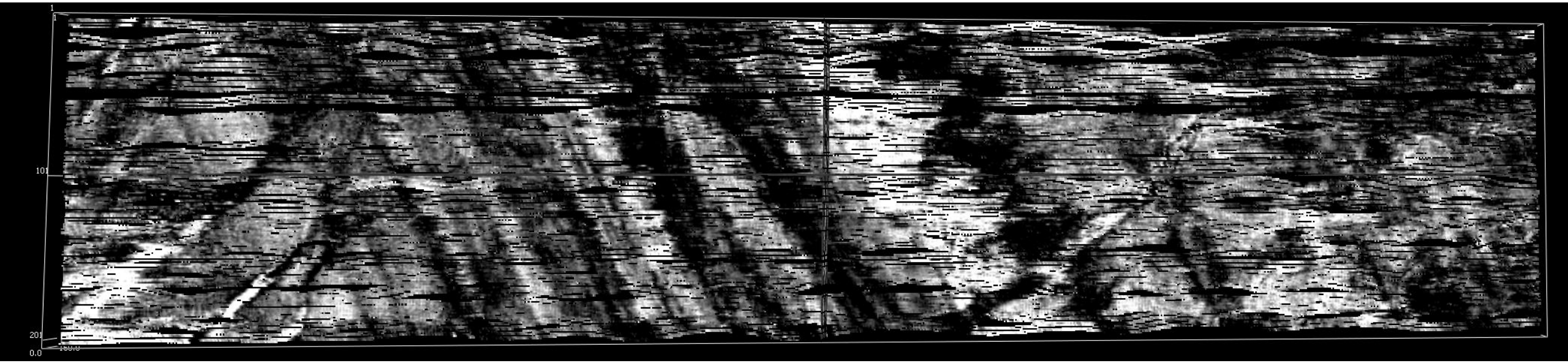
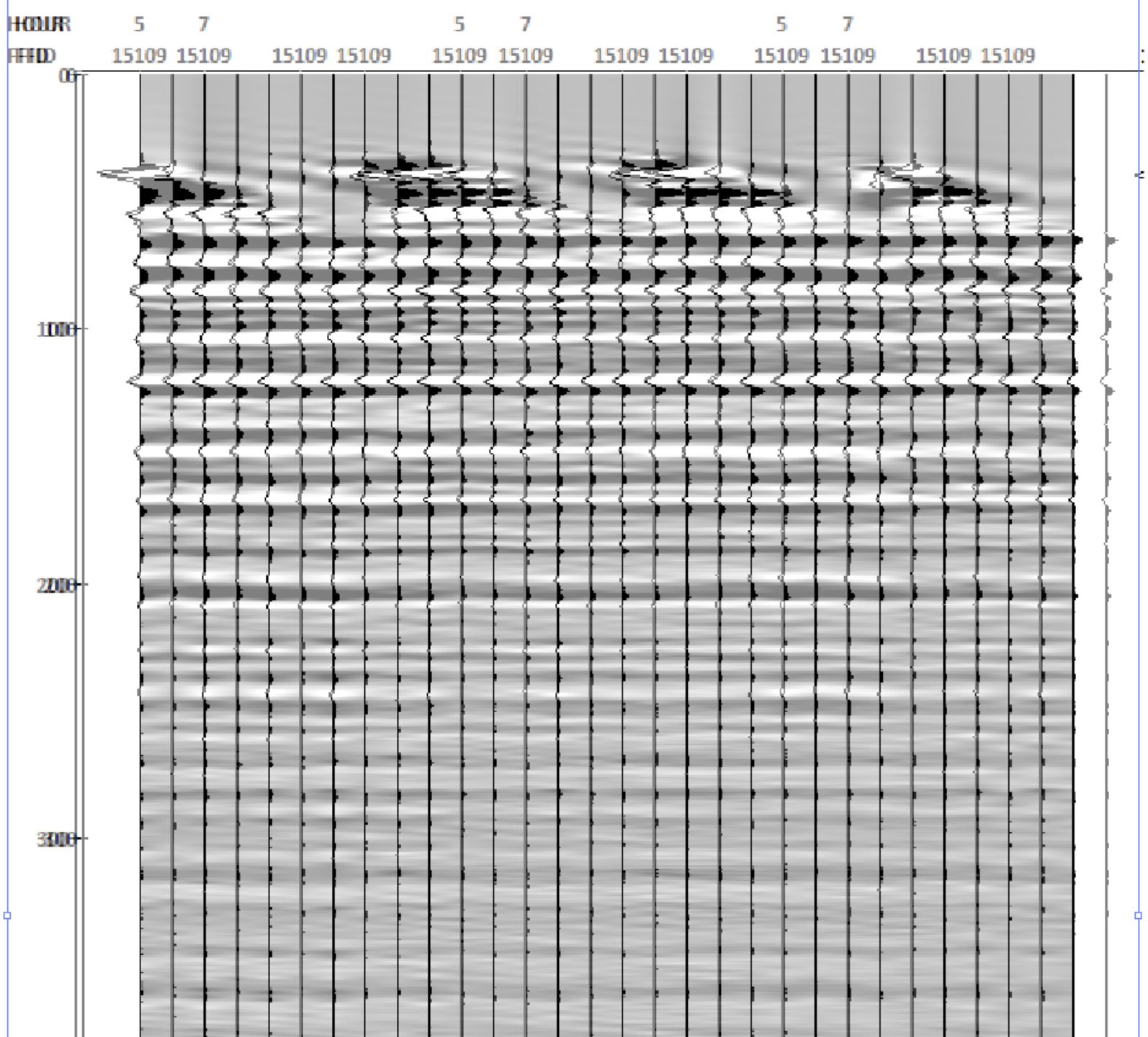
12:47 PM
3/22/2018


1
1
101
201
0.0

SUMMARY

1. Theoretical sensitivity study indicated that injected CO_2 should generate a seismic response, but that residual natural gas present may mask the signal.
2. A successful first high-resolution 3D survey has been collected
   - Limited imaging depth (600 ms) = very noisy port environment.
3. Repeatability Study ongoing – initial results look promising for 4D in shallow interval.
   - Demonstration of HR3D as CCS monitoring tool in overburden.
4. A second survey is planned for 2019.

Line 15



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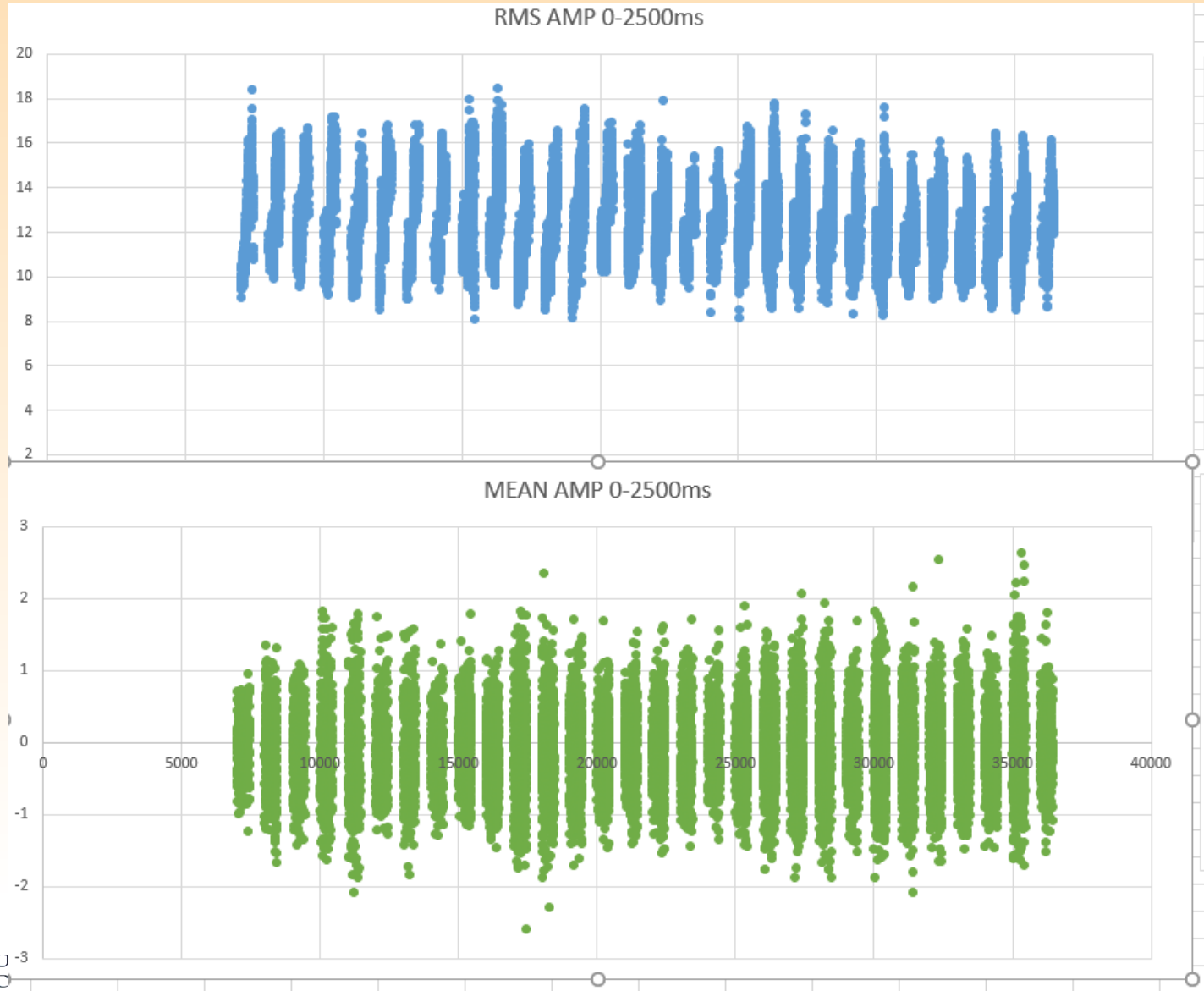
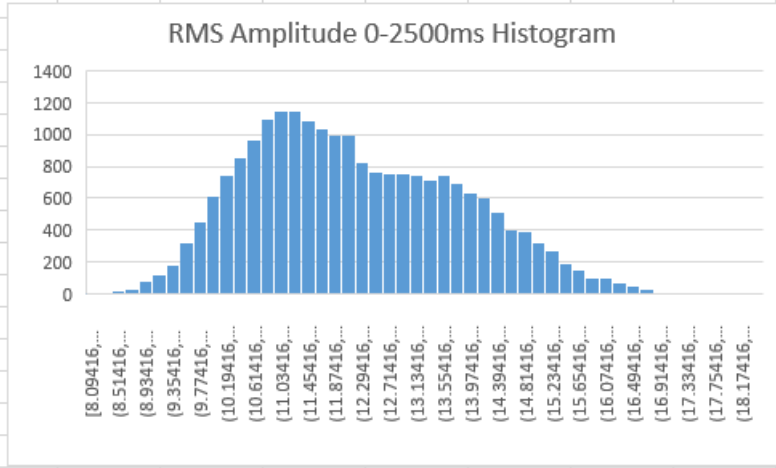
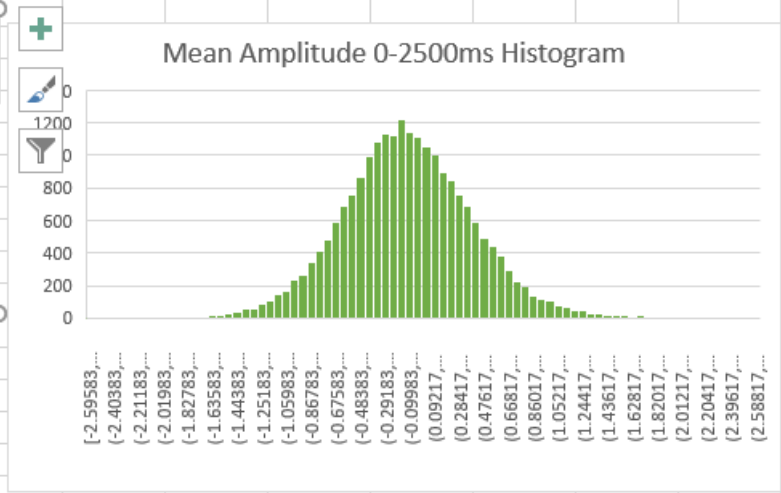
Amplitudes on Raw data 0-2500ms







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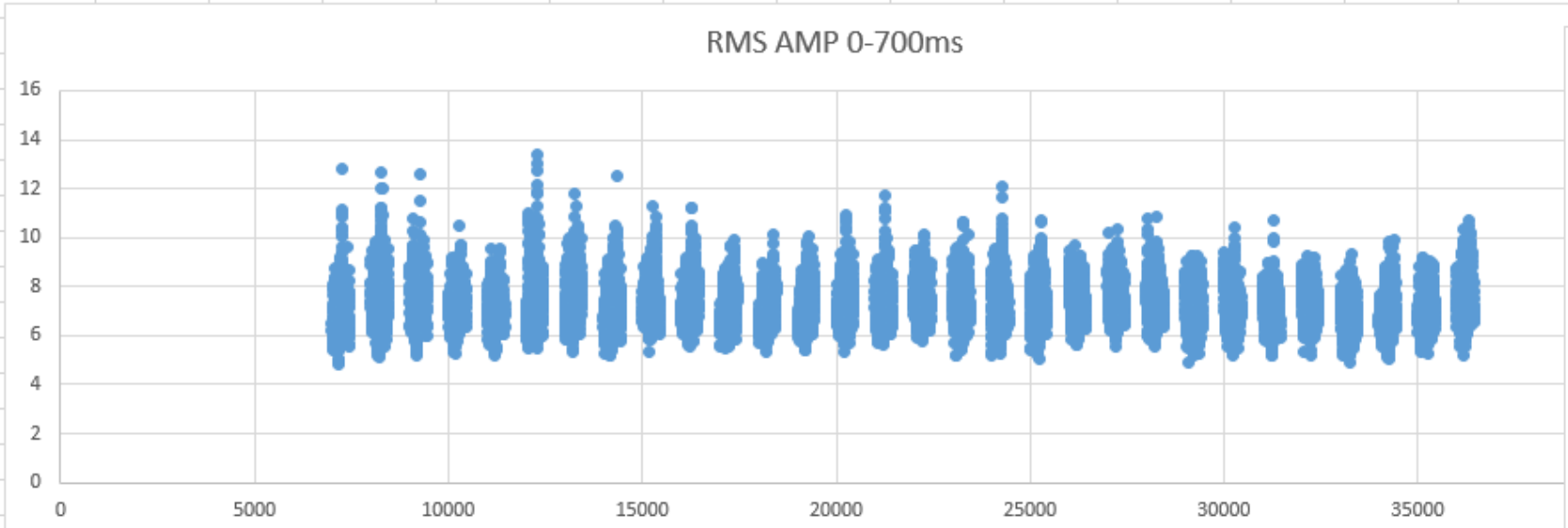
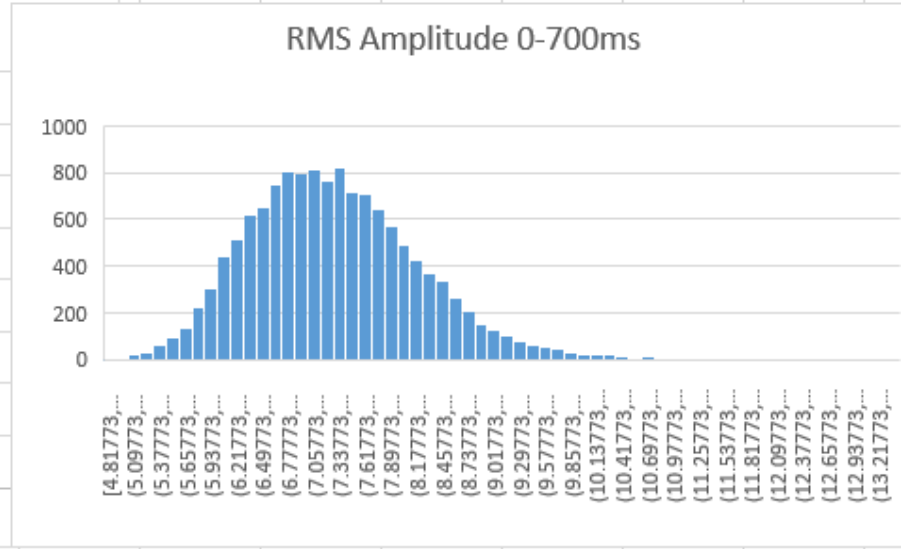
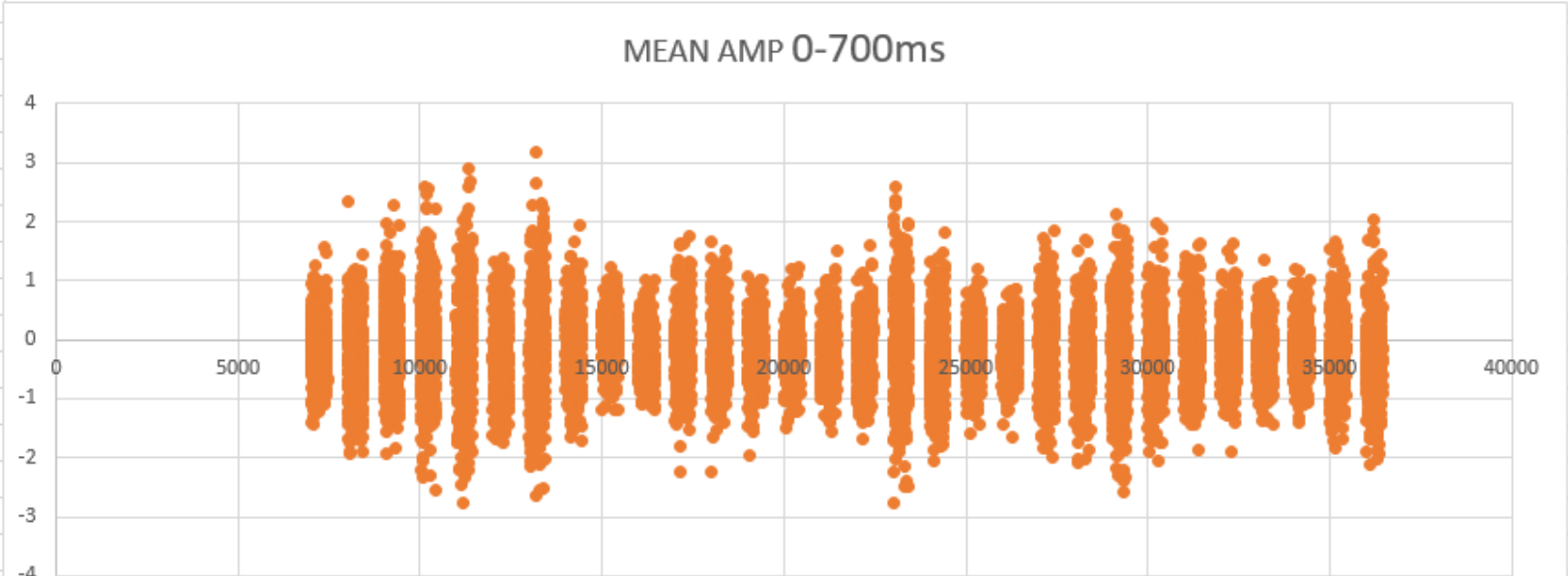
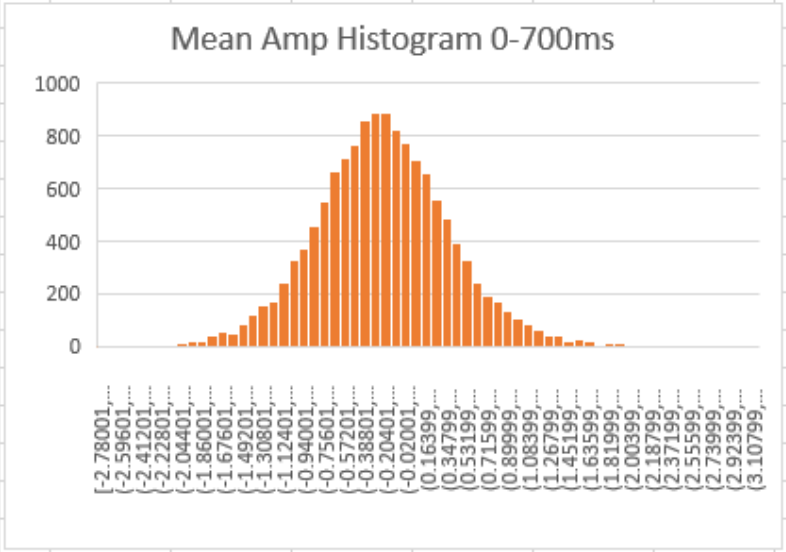
Amplitudes on Raw data 0-2500ms









Comparison by Location, FK spectrum

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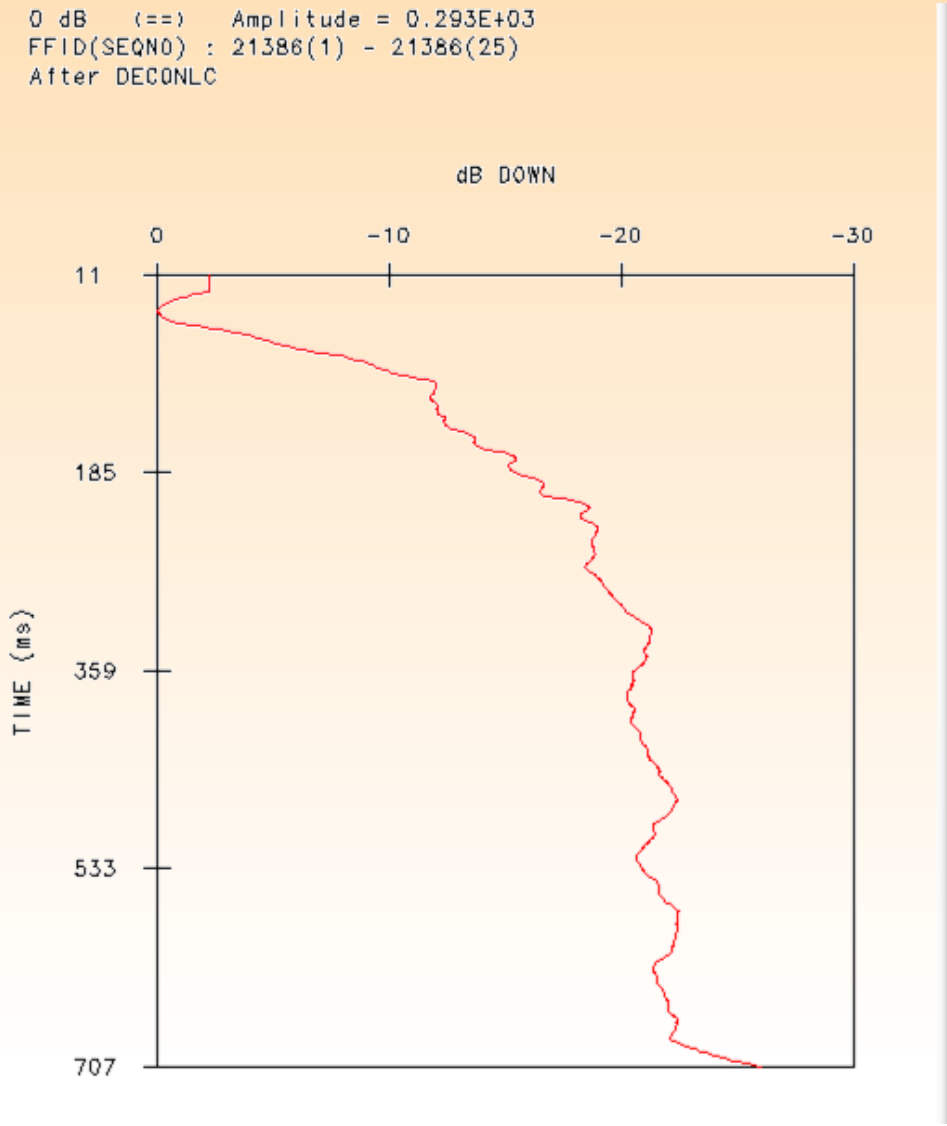
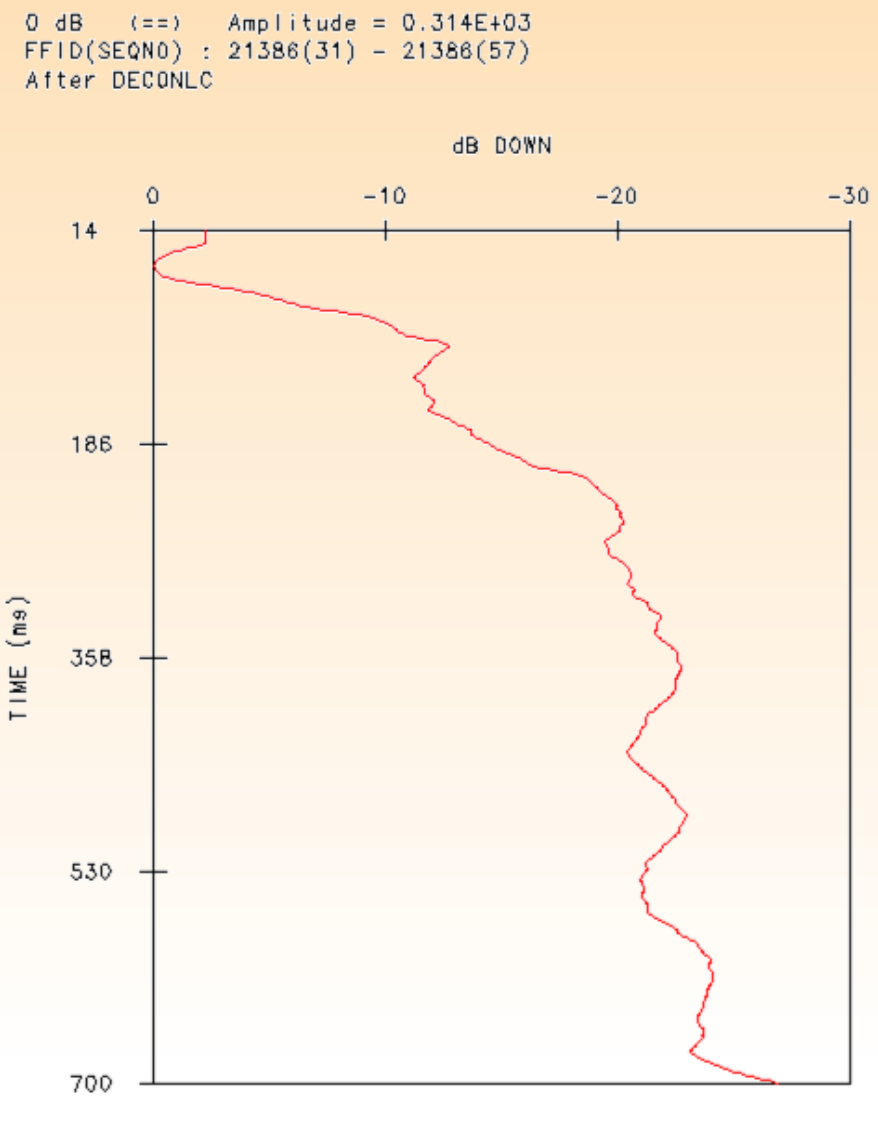
Comparison by Location, Gain





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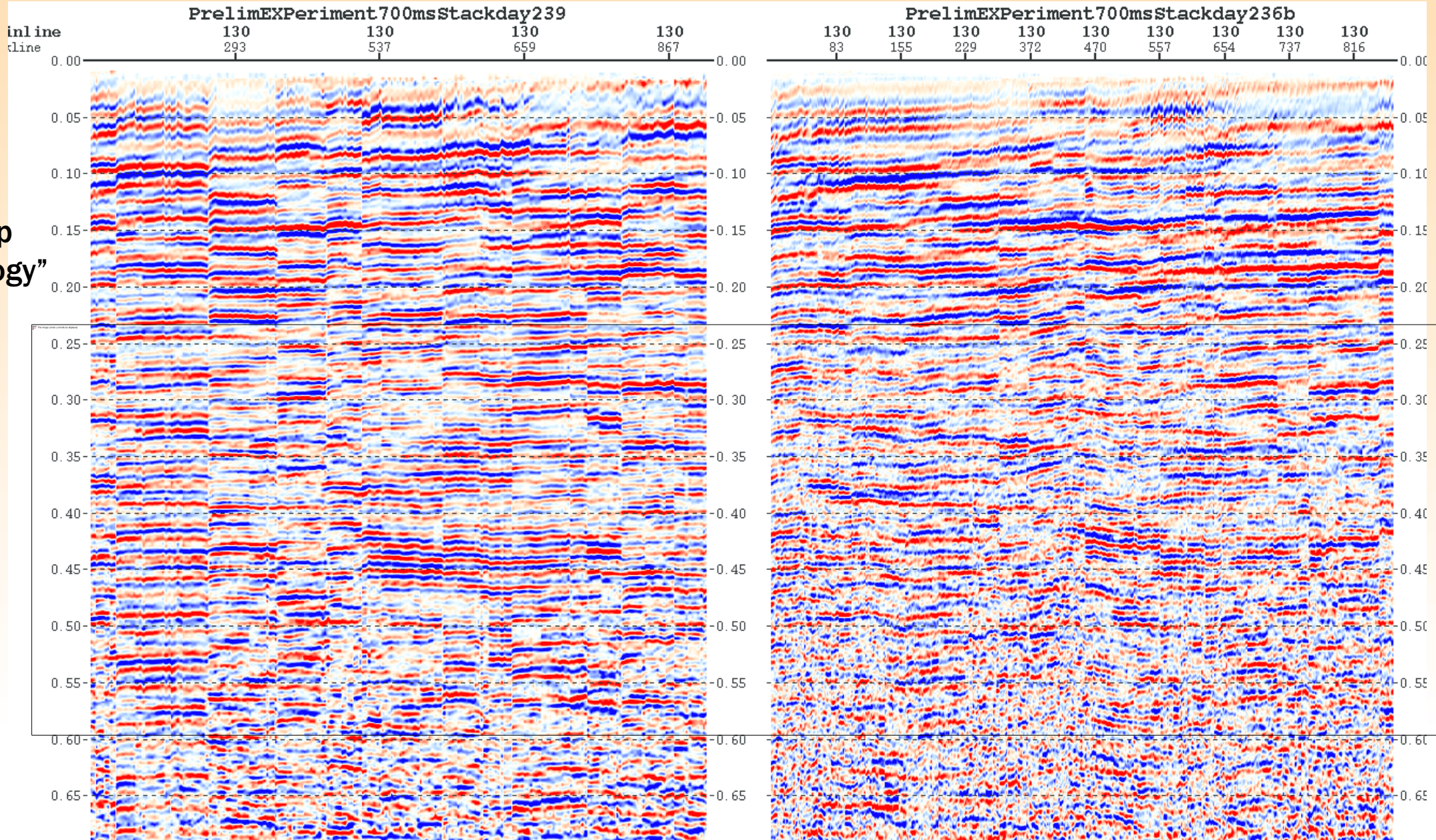
Comparison by Location, Time-Frequency

Post Stack comparisons

Inline 130
Partial Overlap
Similar “Geology”

Very similar spectrums



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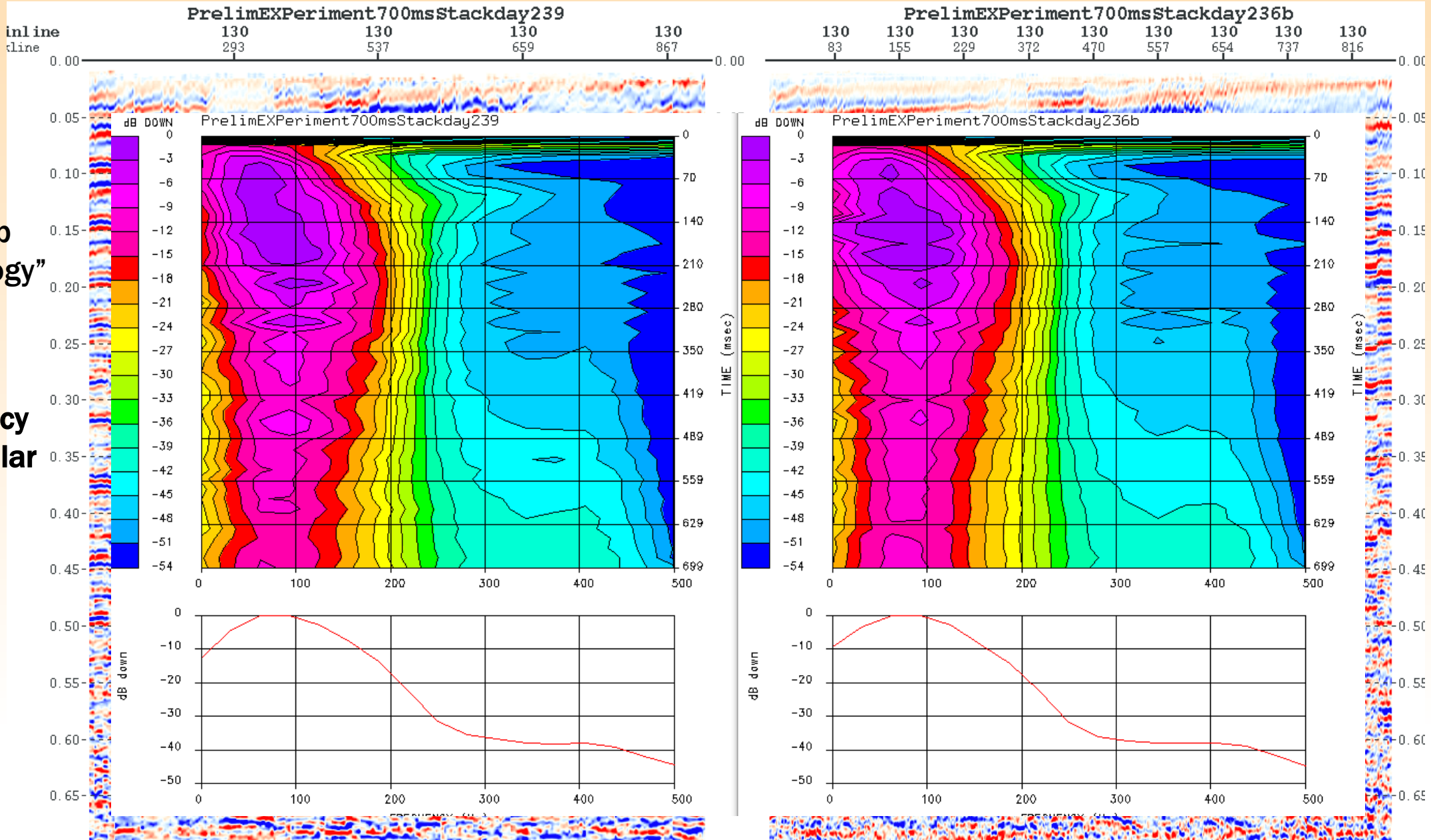
Post Stack comparisons

Inline 130
Partial Overlap
Similar “Geology”

Time-Frequency
Also very similar



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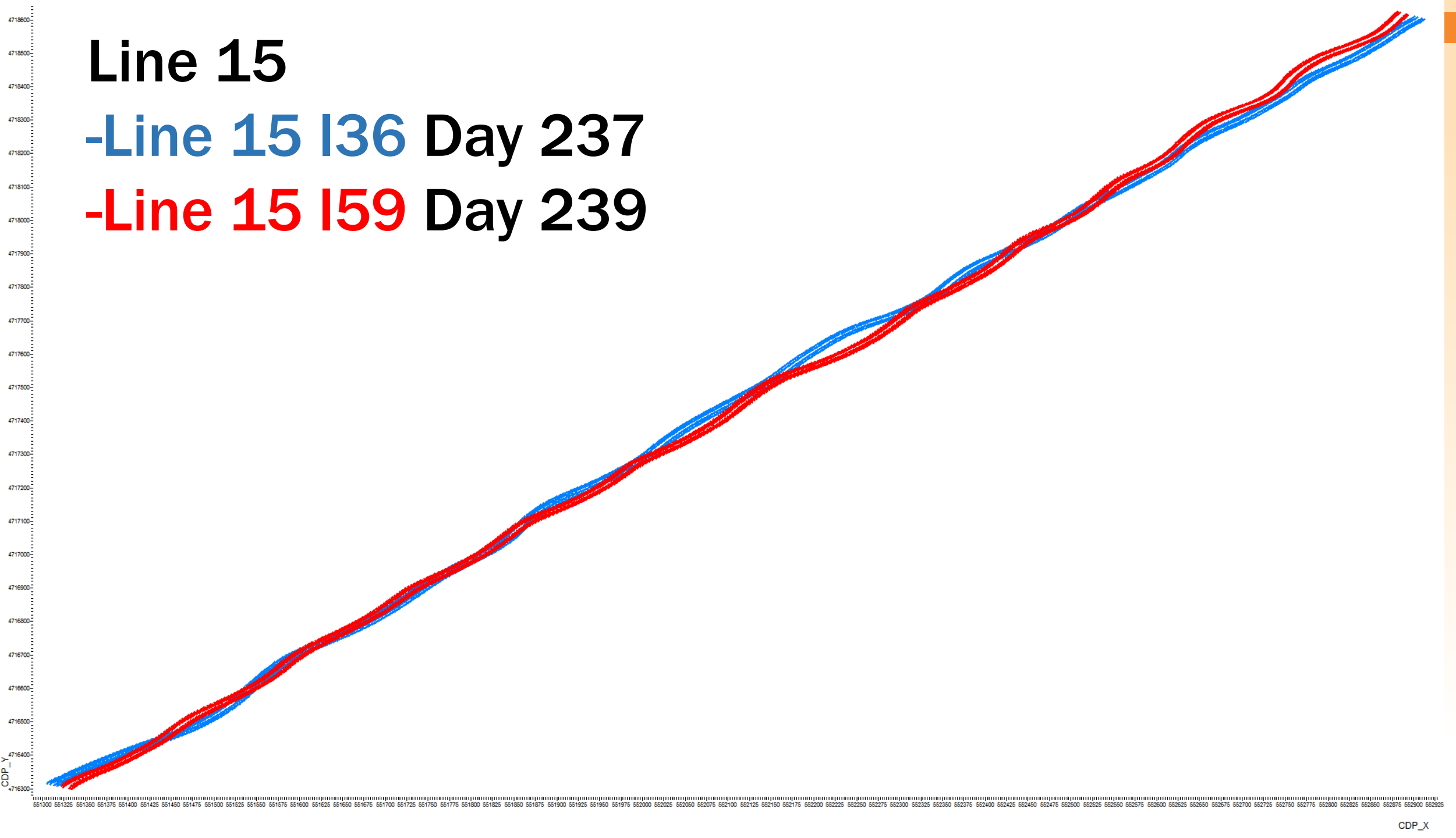
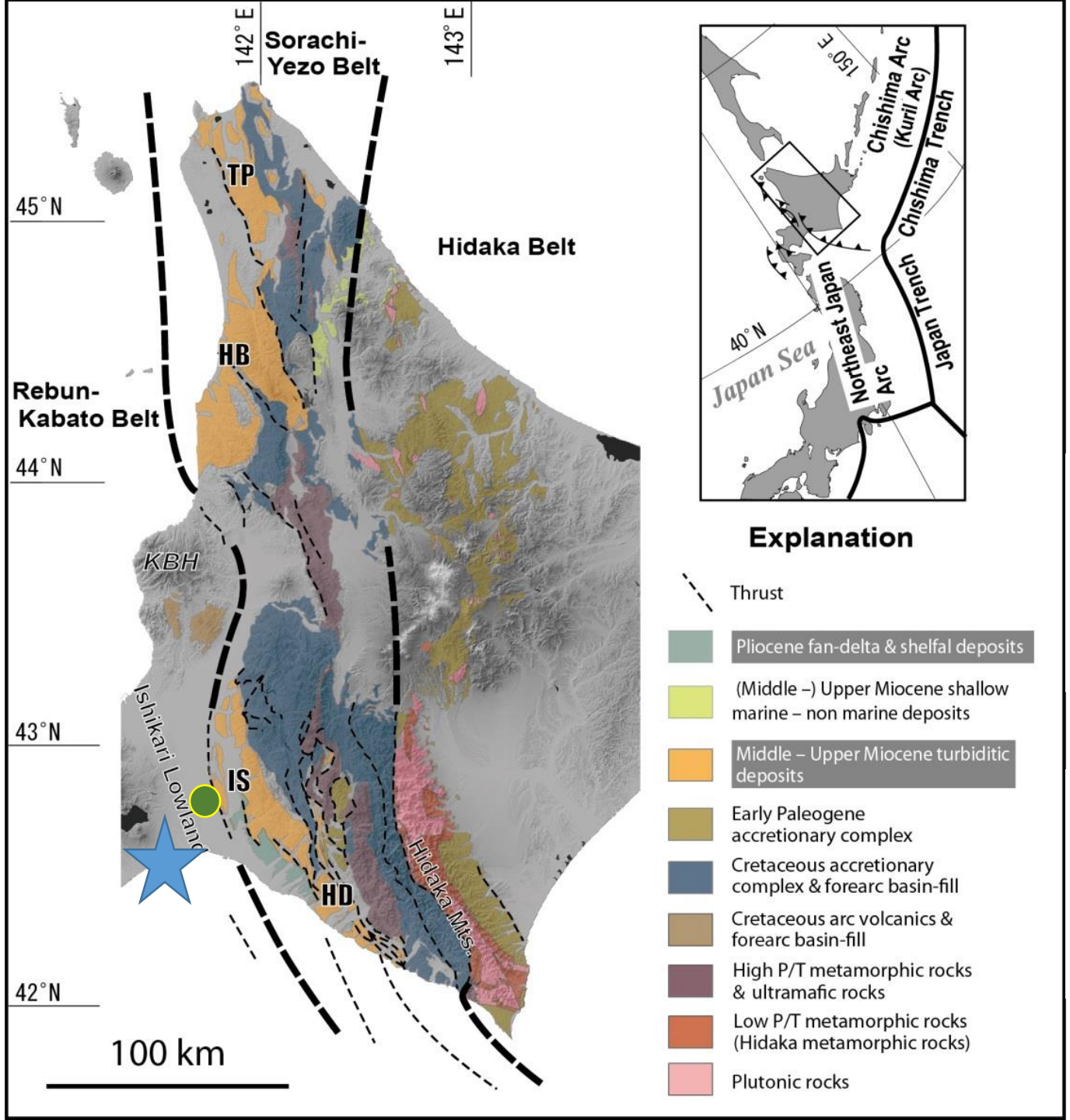
Line 15

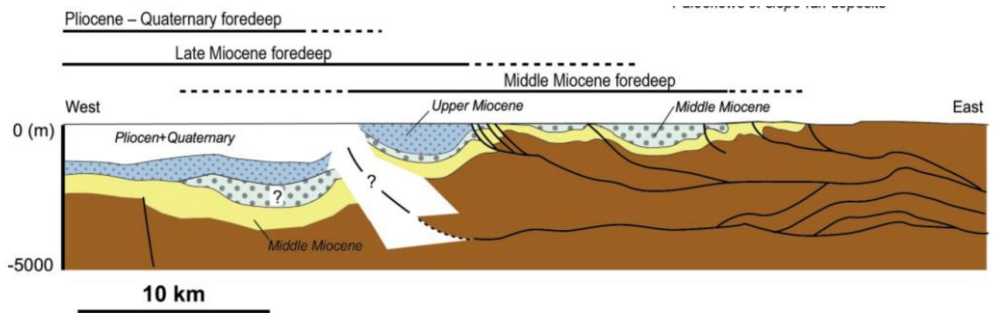
-Line 15 I36 Day 237

-Line 15 I59 Day 239





Yufutsu oil and gas field
JapEx, 1988
Entirely fracture permeability
Up to 40 MMcfd in 2005



GHGT-11

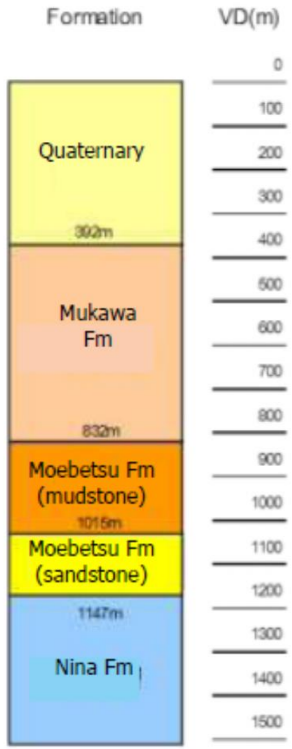
Fault stability analysis related to CO_2 injection at Tomakomai, Hokkaido, Japan

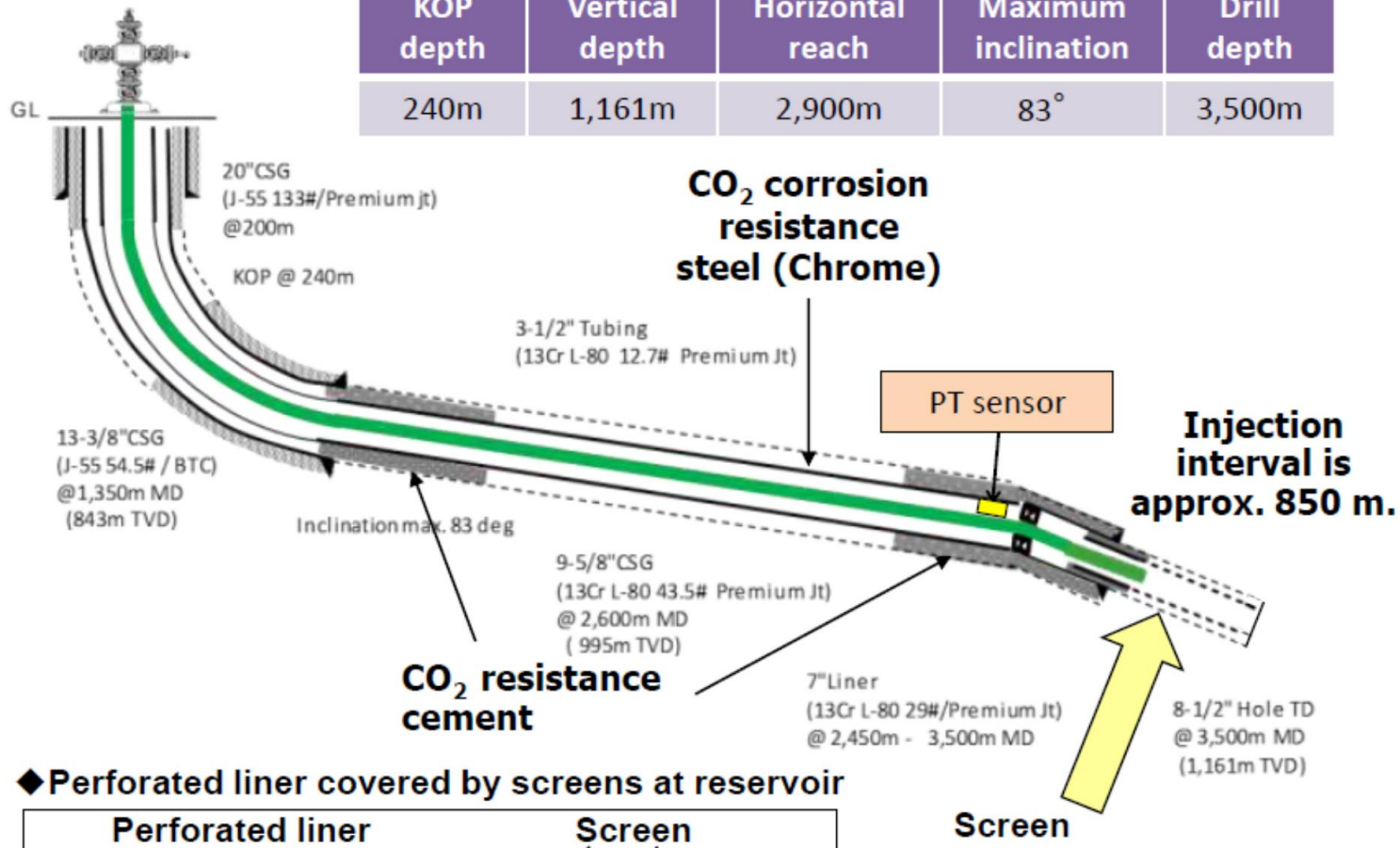
Y. Kano[a]*, T. Funatsu[a], S. Nakao[a], K. Kusunose[a], T. Ishido[a], X.-L. Lei[a], T. Tosha[a]

Injection well for Moebetsu Formation

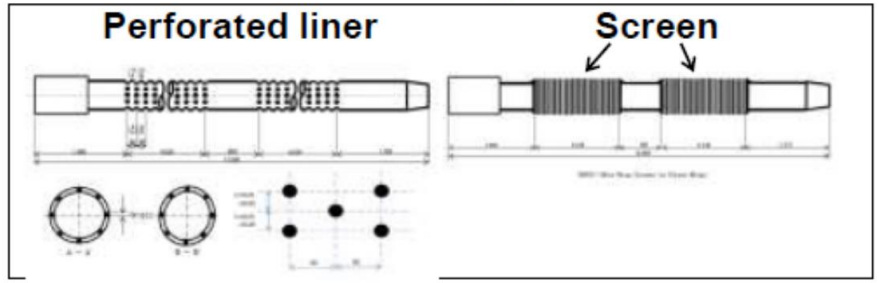
◆ Drilling : 12th March 2015 ～

KOP depth	Vertical depth	Horizontal reach	Maximum inclination	Drill depth
240m	1,161m	2,900m	83°	3,500m





◆Perforated liner covered by screens at reservoir



JCCS