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Abstract No. 23

Use of the vertical CSEM method in prospect de-risking. A dry well case story. The Grind prospect

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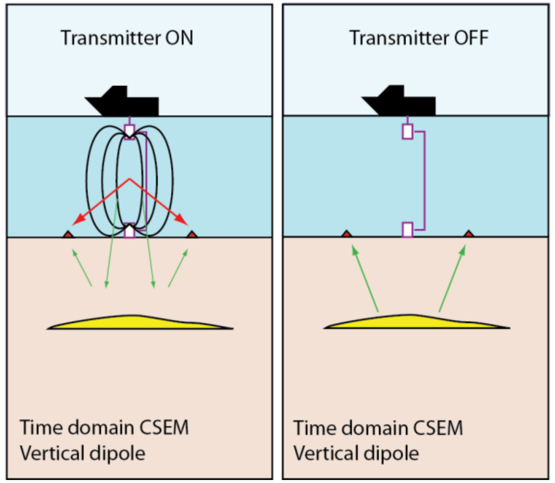
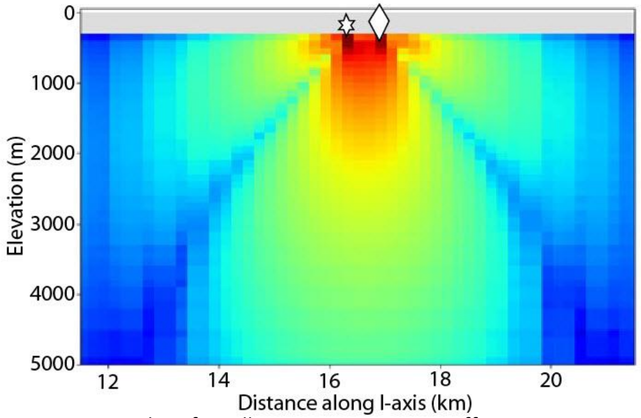
Agenda

- Motivation for Vertical CSEM
- Acquisition principles
- Advances in equipment and acquisition - from 2D to 3D
- 3D Case study: Grind prospect
- Conclusions

Motivation for Vertical Controlled Source Electromagnetics



Time domain VCSEM



VED-VED subsurface illumination at 500 m offset in 300 m sea depth.
Visualization from 3D calculation of (WJ)^T WJ diagonal for pv

- CSEM: map resistivity distribution in subsurface
- Detection of thin resistive bodies used in hydrocarbon exploration
- Dipole antenna transmitter and receiver
- Dipole orientation has effect on the electromagnetic field propagation through resistivity boundary conditions, and therefore also affects the sensitivity distribution
- Time domain processing and interpretation
- Time domain vertical dipole source sees maximum sensitivity at short offsets and late time
- High sensitivity to smaller deep targets
- Subsurface illumination in localized volume below transmitter and receiver
- Measurement not affected by resistive features outside volume of illumination, thereby reducing risk of misinterpretation

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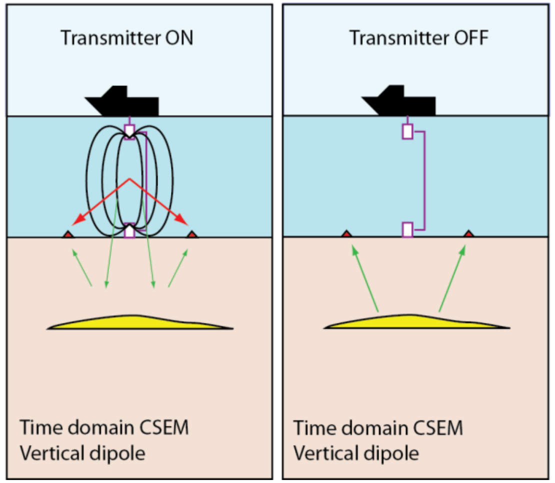
VCSEM Acquisition Principles

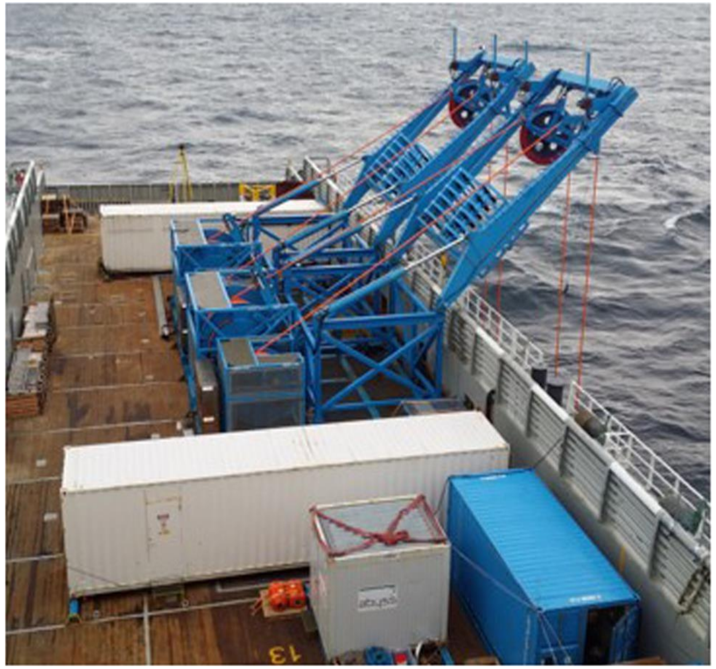


Time domain VCSEM

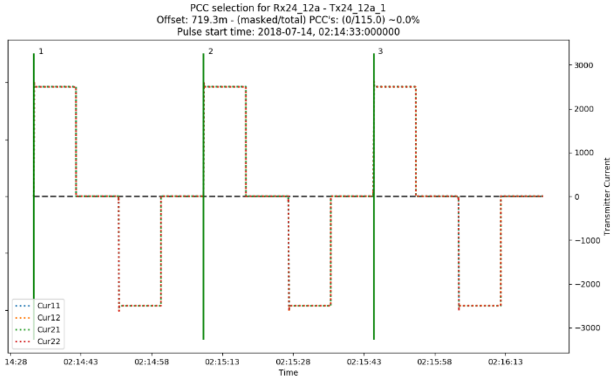
Vertical CSEM in operation – vessel backdeck during transit

- Vertical electric dipole transmitter
- Vertical and horizontal dipole receivers
- Both transmitter and receivers are stationary during recording to allow noise reduction through stacking
- Stack period typically 30-60 minutes
- Strict requirements for verticality
- Time domain transmitter signal (transient)
- Focus on short offsets (~1-2 km)
- Modular kit for vessel independence – platform supply vessel or multi purpose vessel with DP2 capability

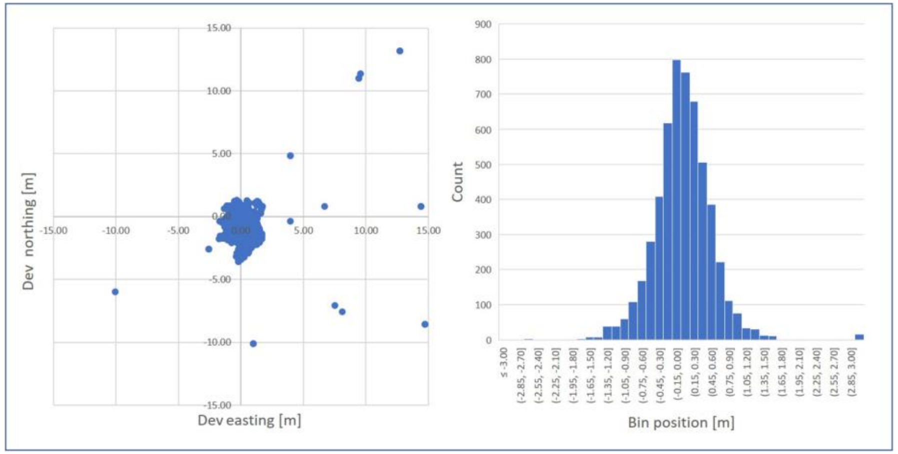
VED Transmitter system



- Vertical electric dipole
- Max output 3000 A – 2 systems can be run individually or in parallel for up to 6000 A
- Current fed to source electrode with low impedance cable
- Sea bed electrode positions measured with acoustic short baseline telemetry and fixed in vessel DP system
- Stationary during transmission
- Position of upper electrodes continuously controlled with acoustic telemetry
- Typical length: sea depth – 50 m
- Source signal: Thue-Morse sequence with square pulses of different polarity followed by listening periods

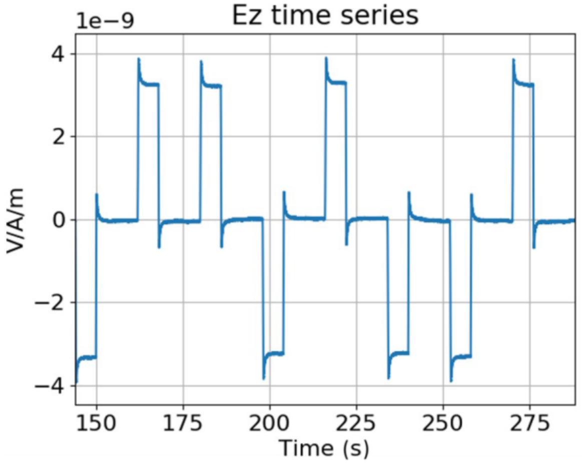


P2 9s+9s waveform

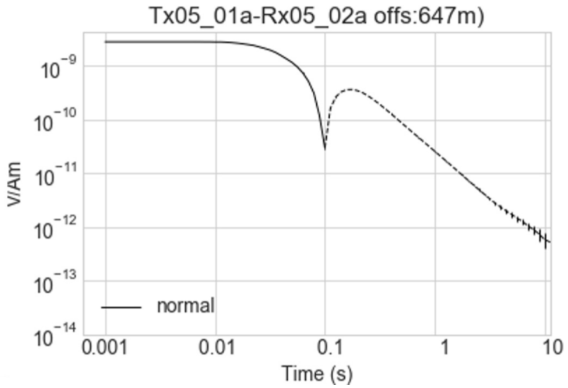


Measured position of upper electrode during 90 min transmission

VED Receiver system requirements



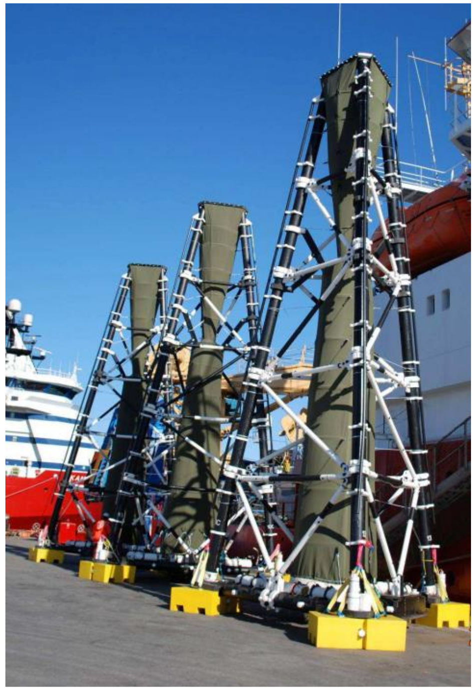
Part of single recorded ransmission series



Stacked transient response in log-log domain.

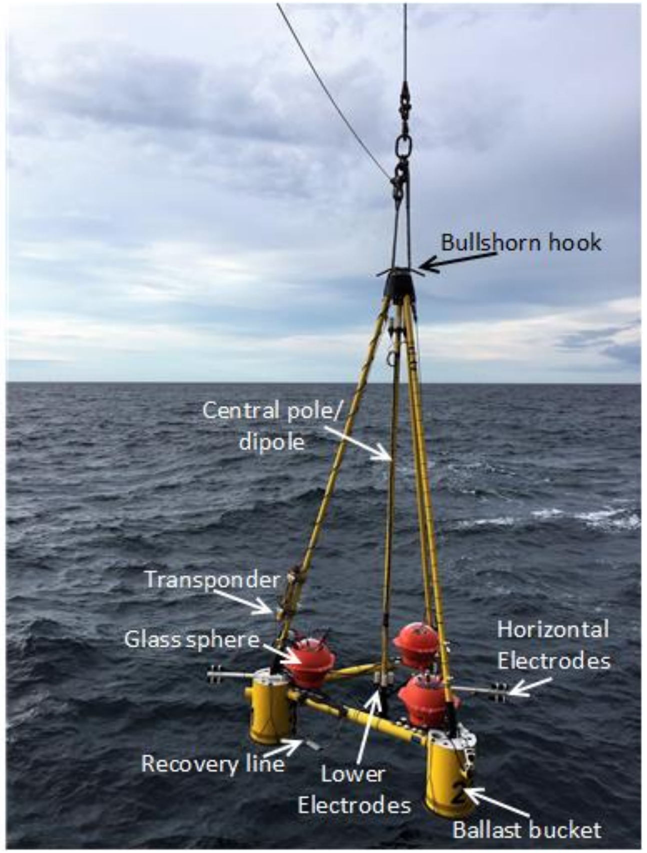
- Recorded signal amplitude can span 6 orders of magnitude
- Large dynamic range and low noise floor
- High bandwidth and sampling frequency
- High precision time synchronization between transmitter and receiver
- Strict verticality requirements to avoid signal contamination
- Autonomous deployment and recovery for 3D acquisition
- Communication with receiver while on seabed
- 30+ receivers per Tx for 3D coverage in near zone

Previous generation of VCSEM receiver (pre-2016)



- Large structure with 10 m antennal to meet noise requirements
- Deployed with crane and ROV
- Passive verticality adjustment
- Size and weight prohibitive for 3D acquisition

VCSEM Tripod receiver Mk. 5



Tripod receiver lauched 2016

Reduced dimensions:
- Full height: 5 m
- Base width (side): 2.5 m
- Mass in air: 270 kg without ballast - 430 kg with ballast
- Mass in water: 70 kg

- Frame of Glass Reinforced Plastic and PolyOxyMethylene plastic

- 3.6 m VED antenna – 4 parallel recordings on center pole

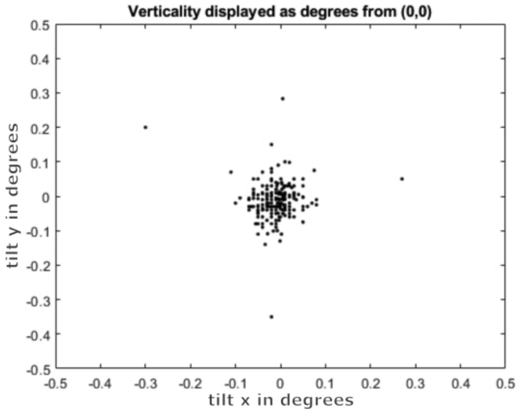
- 2 Orthogonal 3.5 m HED antennas

- Chip scale atomic clock

- Verticality sensor connected to control unit for active verticality alignment

- Verticality checked regularly while deployed

- Release mechanism
    - Sand ballast distributed in corner buckets
    - Secured with polyethylene ropes combining high tensile strength with a low melting point
    - Release based simultaneous heating of all ropes, usually triggered by telemetry signal

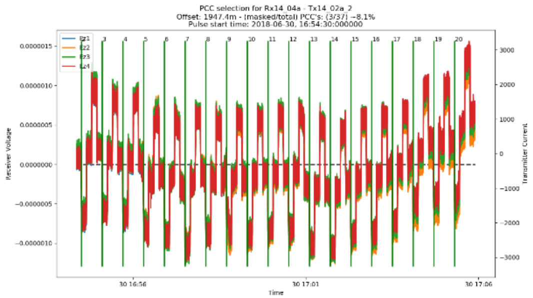


Deviation of centre pole from verticality at 221 locations

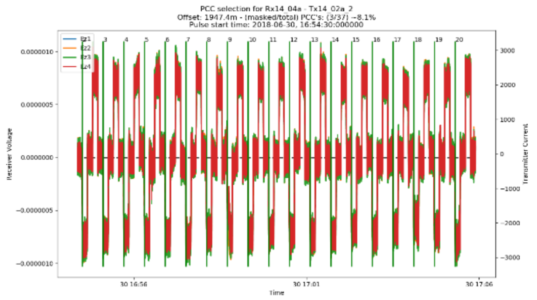
Receiver immediatly after release from sea bed

Processing workflow: Time Domain Stacking

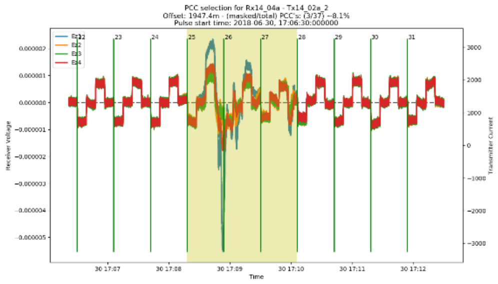
ORIGINAL RECORDINGS



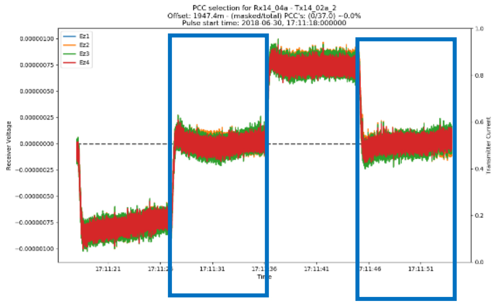
HIGH PASS FILTERED DATA



SPIKE DETECTION AND REMOVAL

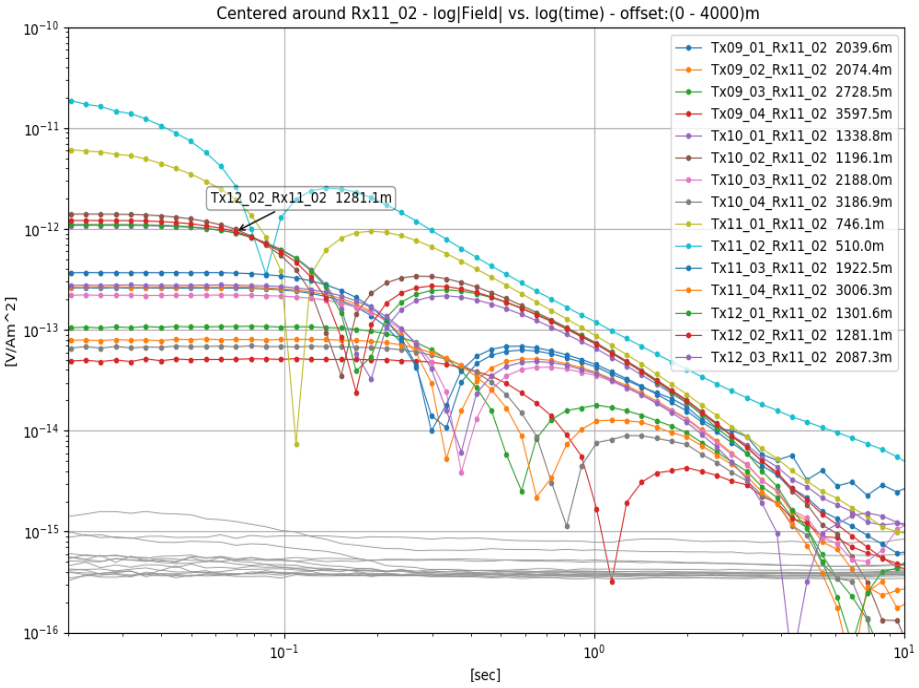


LISTENING TIMES TO STACK



Robust TD stack

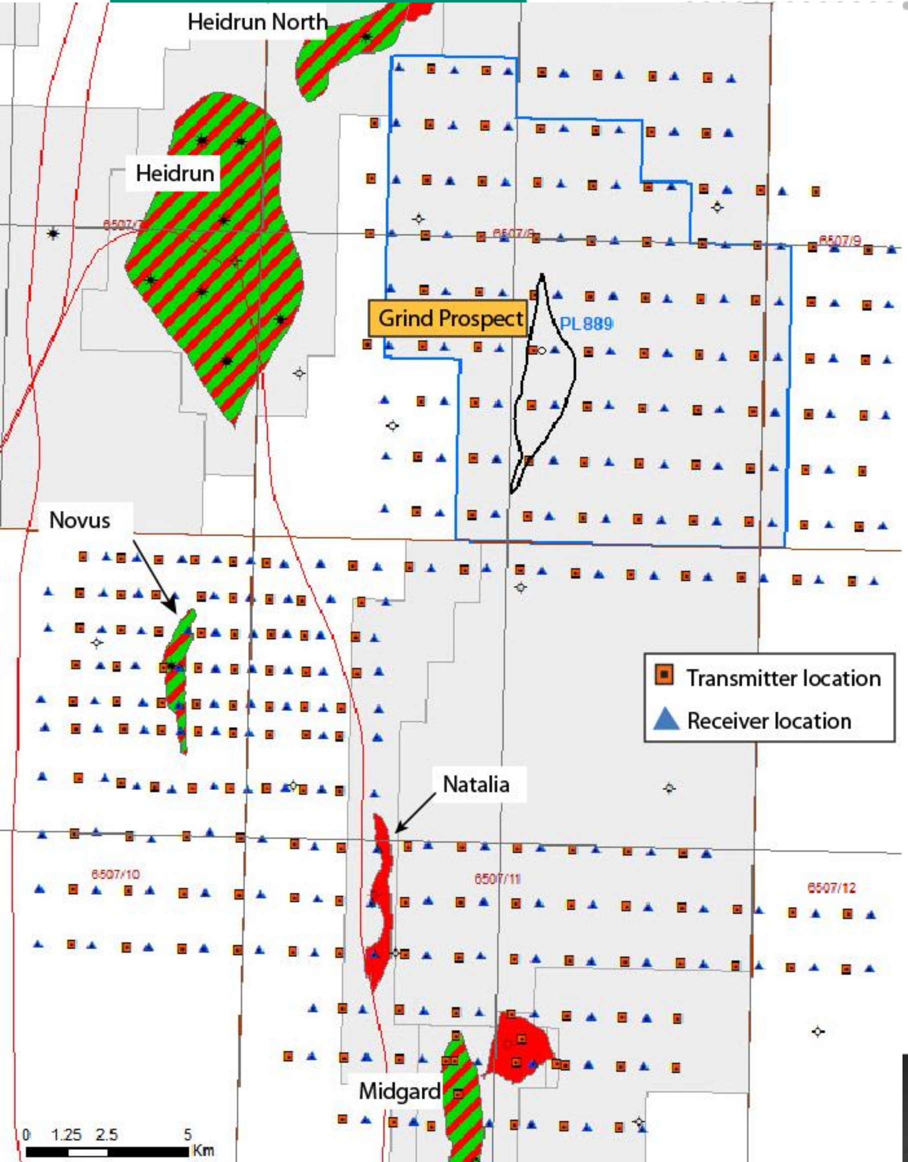
- Noise suppression to reduce low frequency trends with several steps of transforming and high pass filtering the recorded sequence
- Recorded pulse sequence of each channel is chopped up into pre-stack data.
- On the pre-stack a robust recursive algorithm that utilize a statistical framework to detect spikes and whole response outliers is applied
- All receivers have 4 Ez channels. These are automatically weighted and stacked together based on noise performance.



Example receiver gather: Rx with 15 Tx < 4 km

TO STACK

PM17250 Multi-client acquisition



480 km^2 extent – Concedo area of focused exploration

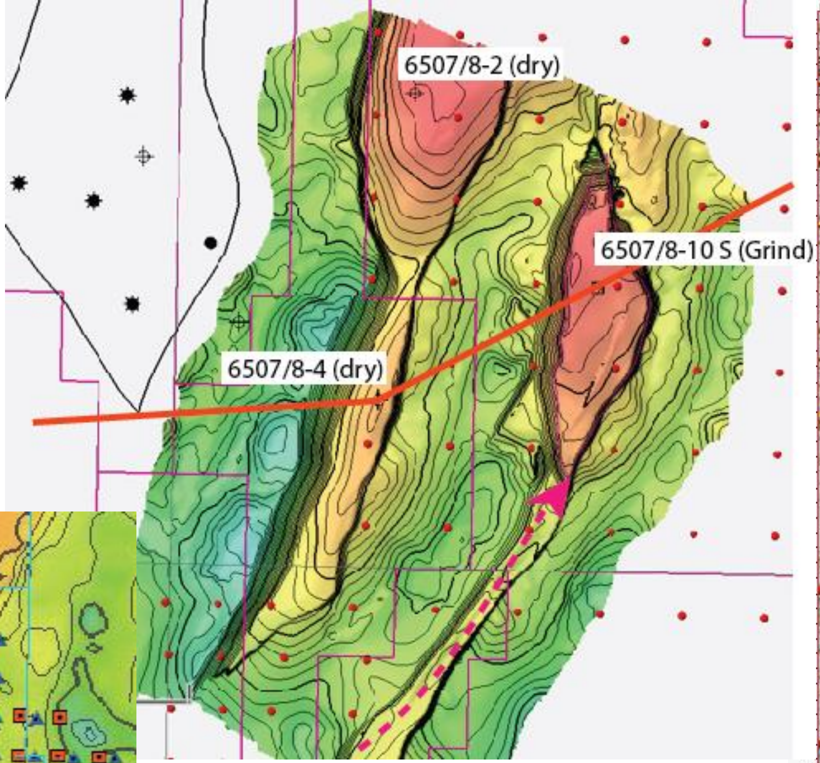
Tie to known discoveries/fields

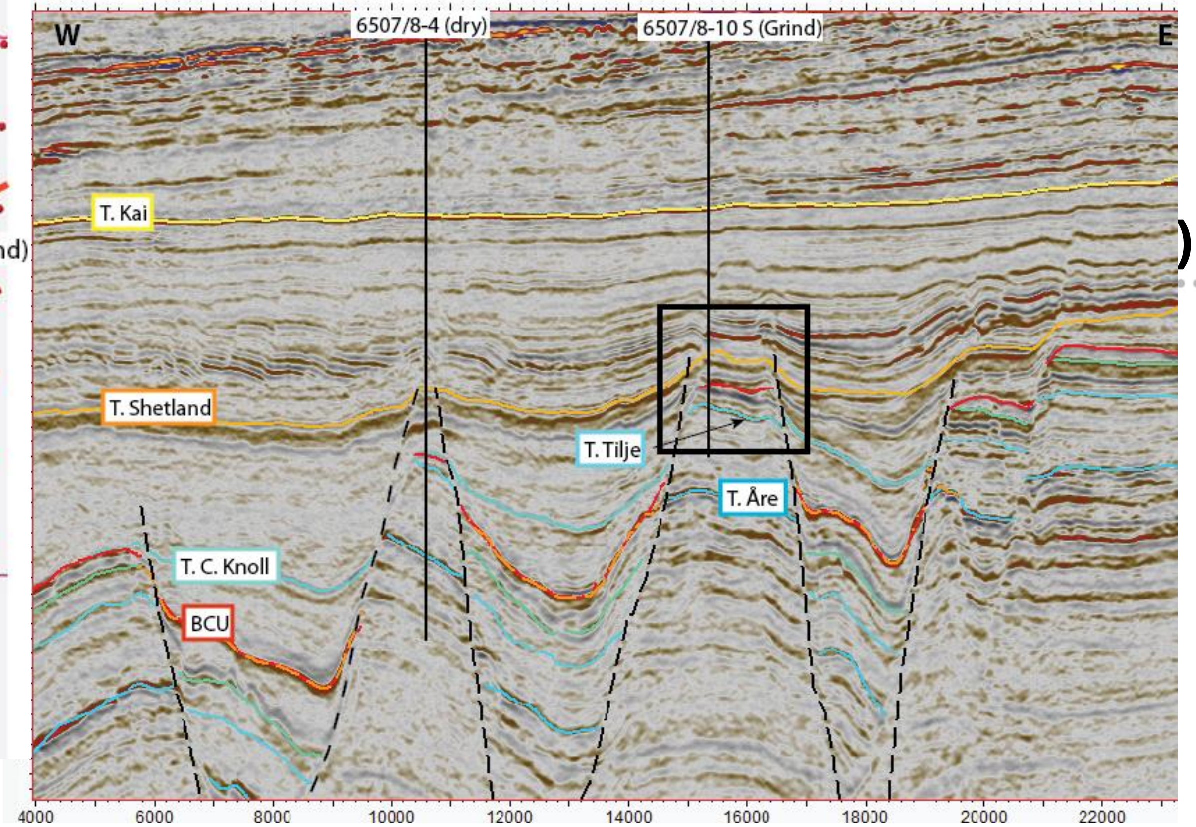
221 receiver / 211 transmitter locations

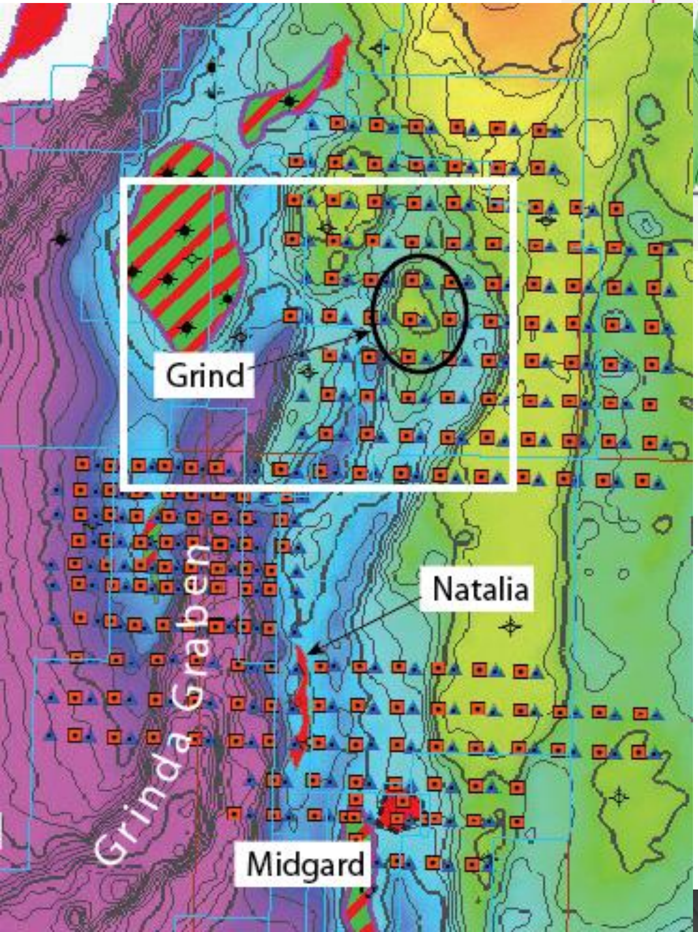
Receiver spacing 1700 m (dense spacing 1100 m)

PL889 in northern acquisition sector – Grind prospect location

Concedo partner in PL889 (Neptune operator) before drilling Grind Prospect







Grind horst – prominent 4-way closure in mature area (exciting to drill?)

Target – Mid Jurassic play (Fangst and Båt groups)

Main risk – migration (two dry structures west of Grind)

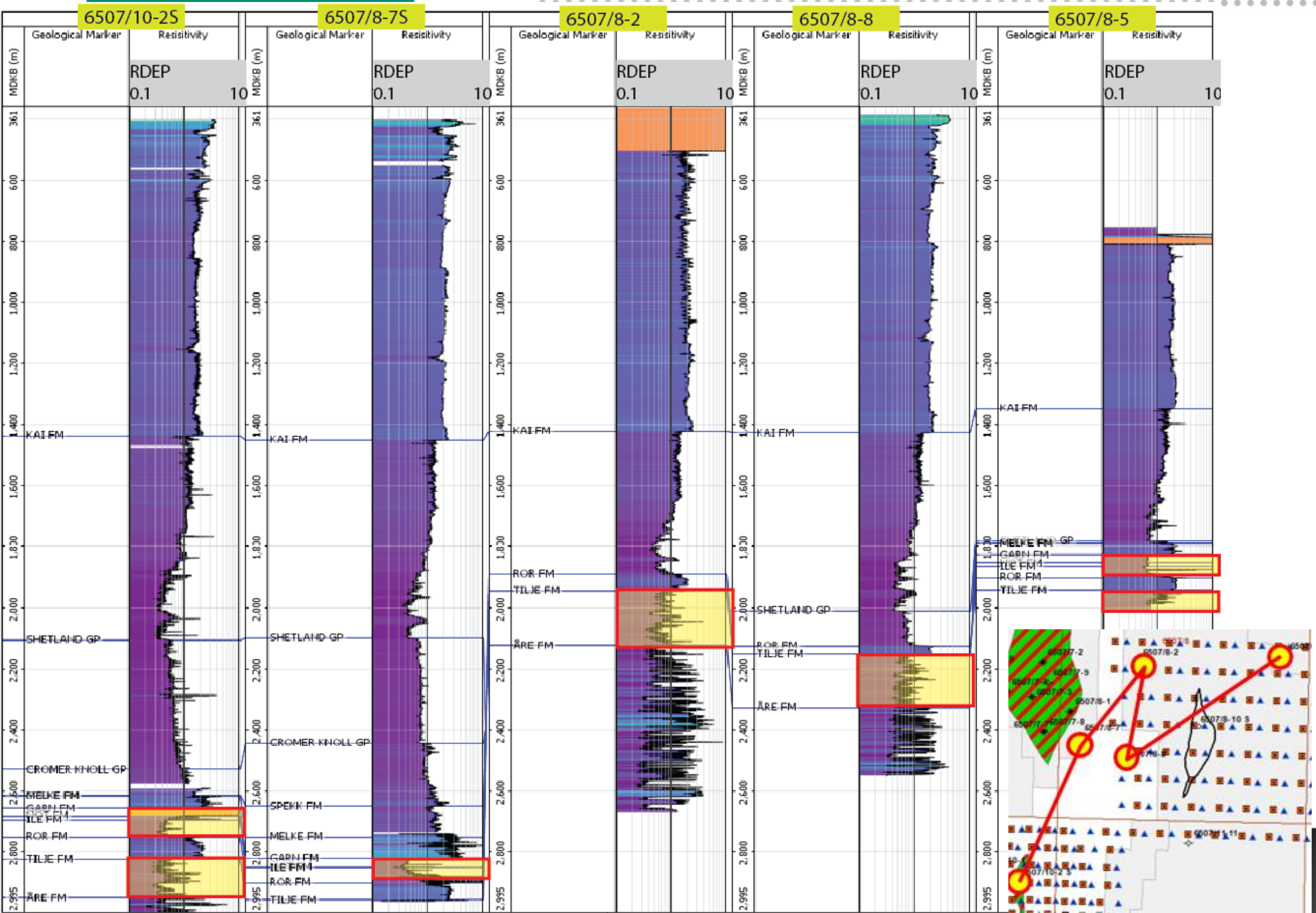
Alternative migration path along ridge linking Natalia discovery and Grind

No specific seismic support for hc-filled Grind

Concedo early user of exclusive VCSEM data targeting Grind (Petromarker 2012)

Concedo early participant in regional acquisition in 2017 (Petromarker 2017)

EM feasibility – a suitable area



Overall low resistive background geology

Top Kai regional resistivity marker

Melke and Ror fm highest resistive layers (< 3 Ωm)

Overall low risk of lithology-related resistors

Highly resistive oil-filled reservoir analogue (Novus – 100 Ωm) – resistivity contrast enhancement!

EM feasibility – a suitable area

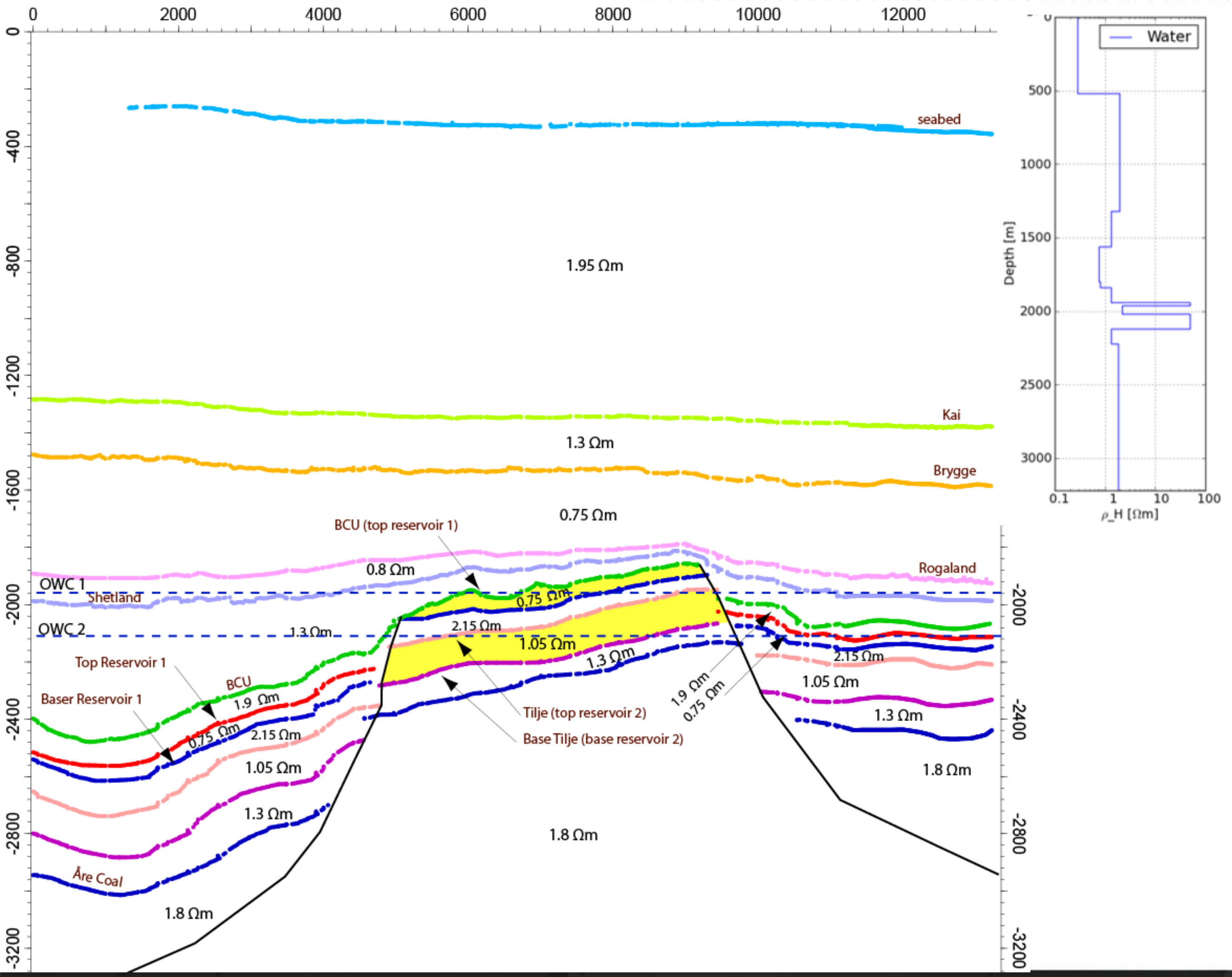
1D feasibility for early acquisition 2012

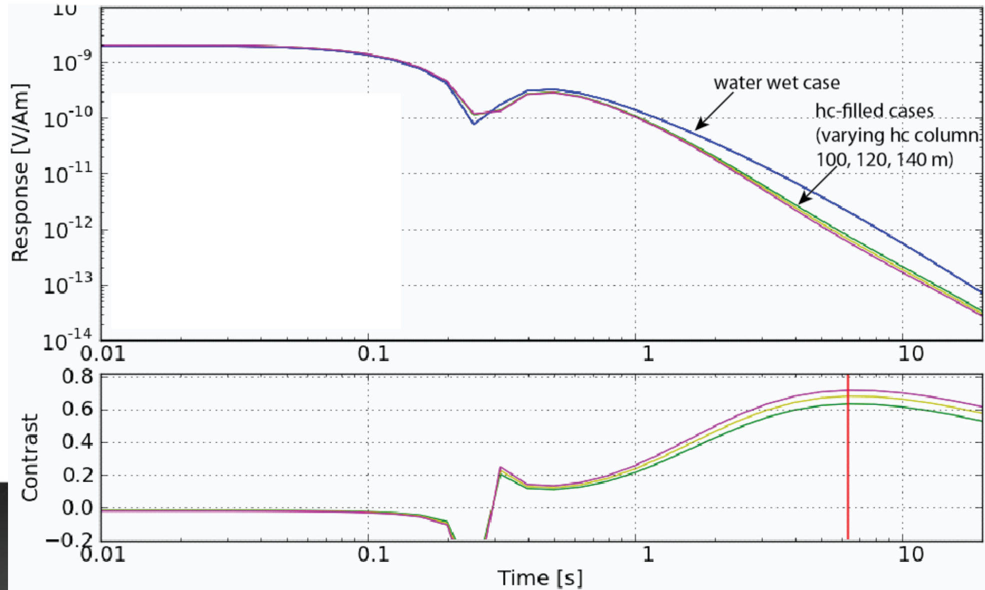
Synthetic model based on well log data from neighboring wells to Grind prospect

Oil-filled reservoir modelled for 50 Ωm

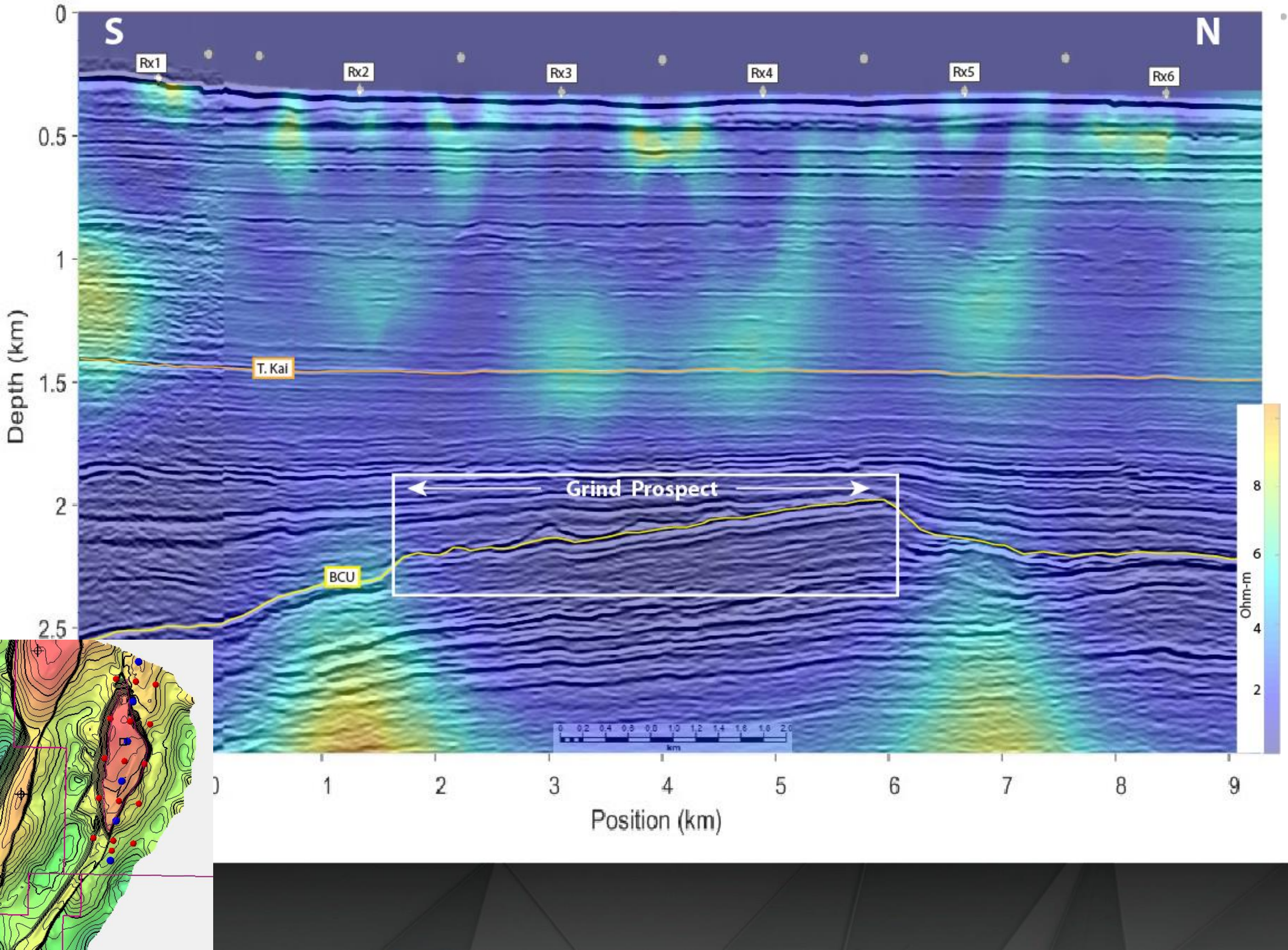
Contrast (wet case vs oil case) > 40%

Positive scenario for VCSEM





PM05-2012 – first setback for Grind



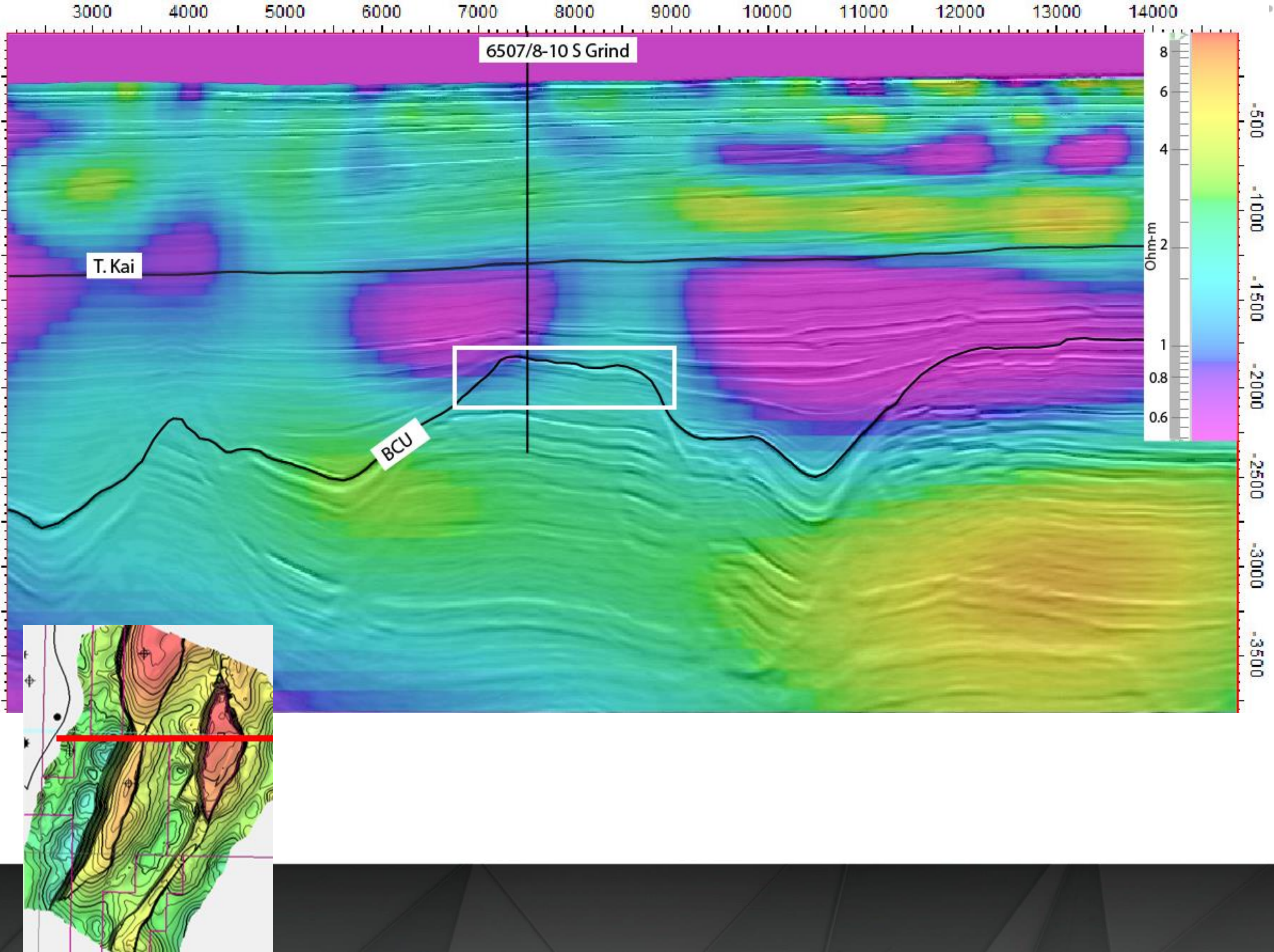
2.5D inversion of early survey data

Moderate resistivity layer above top Kai

Very low resistivity trend throughout lower overburden and Grind target

Resistors at 3 km depth too deep to be interpreted with confidence

Total lack of CSEM anomaly downgrades the Grind Prospect



PM17250 – 2D inversion – still negative for Grind

Inversion of vertical field component from a vertical source dipole

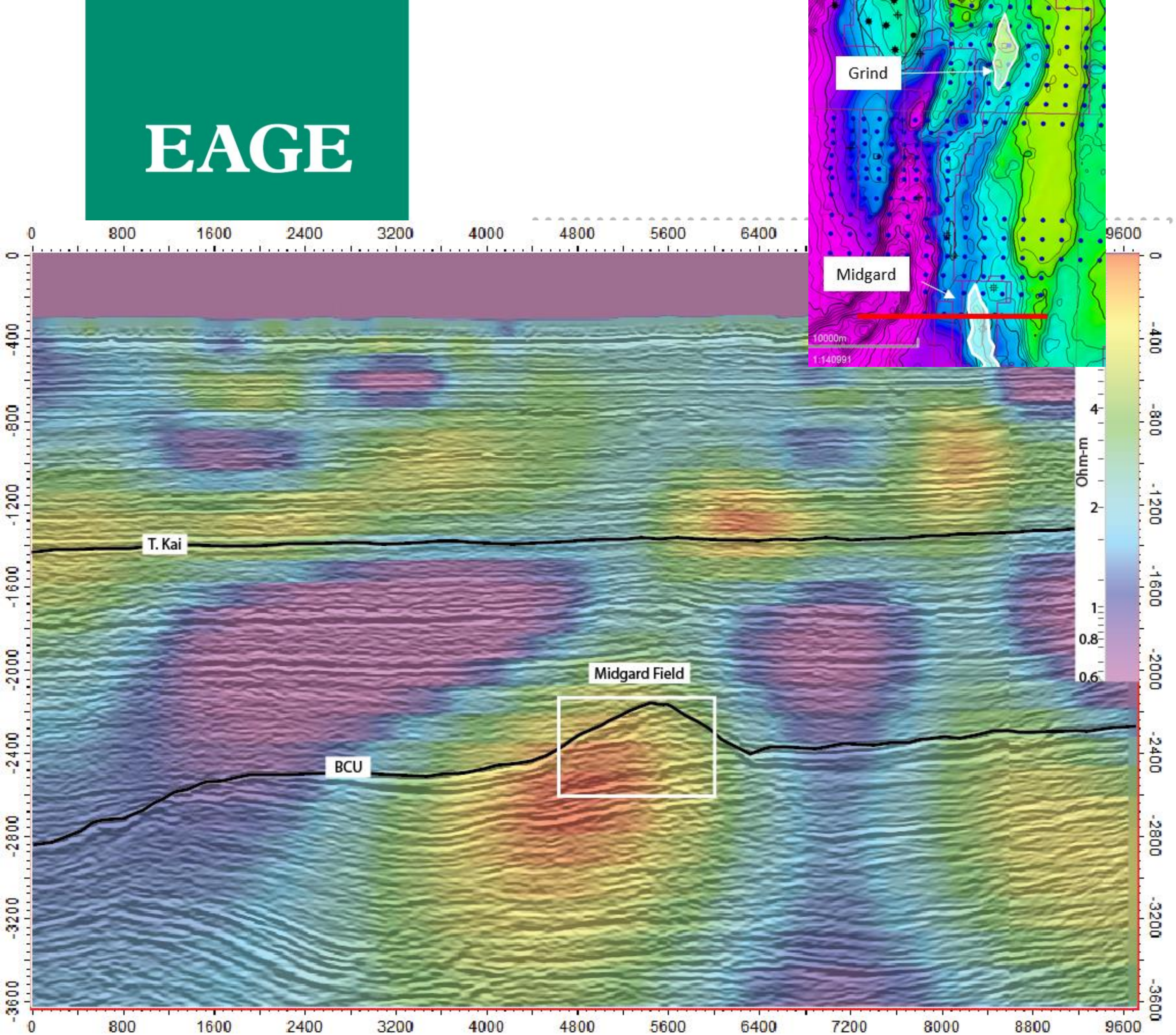
Offsets range 500m-6000m

Unconstrained isotropic inversions

Results consistent with predicted resistivity model

Top Kai as a regional resistivity marker

Low resistive layer 1500m-2300m extends through upper pre-rift relief



PM17250 – Midgard tie
Confidence in inversion results

Northern horst of Midgard Field as analogue to Grind

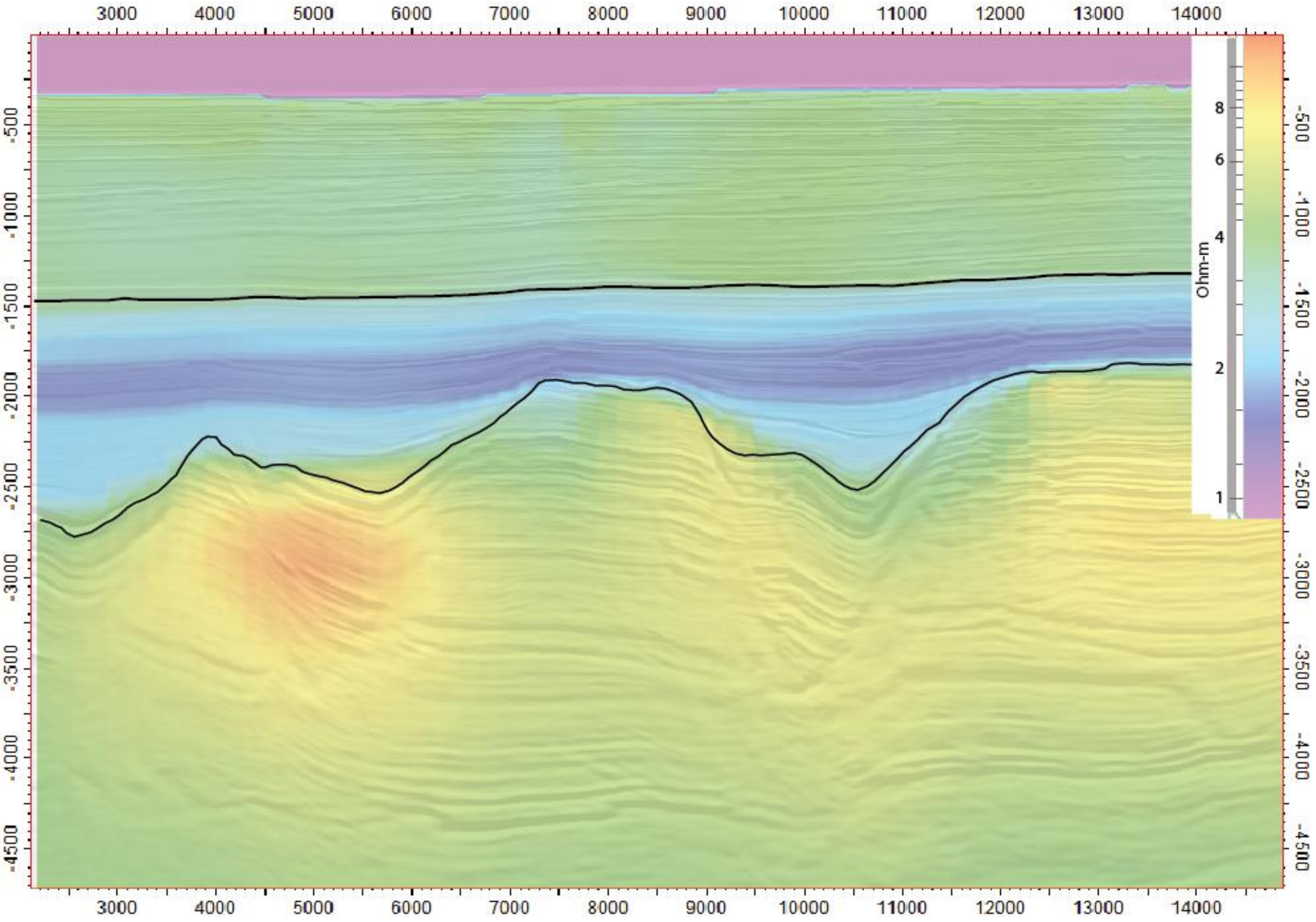
PM17250 line 2 across the horst

Results consistent with predicted resistivity model

2D inversion – strong resistor at field location

Similar anomaly expected for an oil-filled Grind scenario

PM17250 – 3D Inversion



Unconstrained, guided inversion

Data fit somewhat better than 2D but data severely trimmed in offset and time

Novus, Natalia and Midgard show some signature

Lack of anomaly at Grind prospect location is consistent with 2D inversion

Concedo regards 2D inversion more confident than 3D

Conclusions

Use of VCSEM as prospect de-risking tool in suitable contexts proves valuable for Concedo

Grind prospect in optimal context to be de-risked by CSEM methods – strengthens confidence in inversion results!

Grind prospect de-risked twice with VCSEM. Two independent acquisitions, same negative prediction

Total lack of CSEM anomaly at target location deemed Grind a high-risk prospect

Decision to not participate in drilling Grind strongly based on VCSEM results (high risk – low reward)

Absence of resistivity anomalies within range of detection by CSEM is a clear sign of lack of hydrocarbons (or presence of hydrocarbons in marginal quantities)

Use of CSEM in drilling decisions still low in O&G industry – need to improve the rate of commercial discoveries vs drilled wells!