



NORWEGIAN PETROLEUM  
DIRECTORATE



# **A new 3D seismic coverage Southwest of the Troll Field: Possible 4D baseline survey for CO<sub>2</sub> injection in the Johansen Formation ?**

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# Presentation Outline

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- ◆ Introduction / background for project
- ◆ Data Acquisition & Data Processing
- ◆ Results / Mapping of the Johansen Formation in Block 31/5
- ◆ 4D Sensitivity Analysis
- ◆ Conclusions / Recommendations

## Introduction / background for project

- Geological setting
- Some initial findings

# Project background

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- The NPD conducted initial works & mapping in search for locations in NOCS for possible CO<sub>2</sub> storage (Kårstø & Mongstad)

*– end 2007*

*Troll – Johansen* (Block 31/5, open acreage) was identified as a suited location (in parallel with a number of other alternatives)

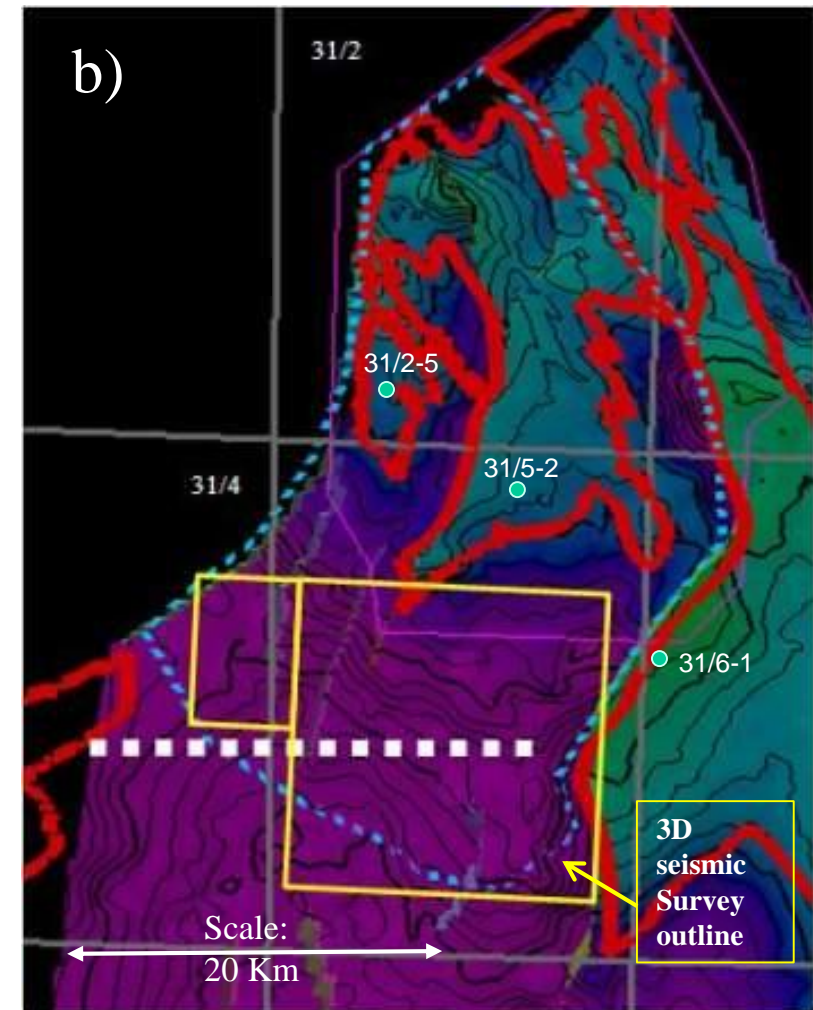
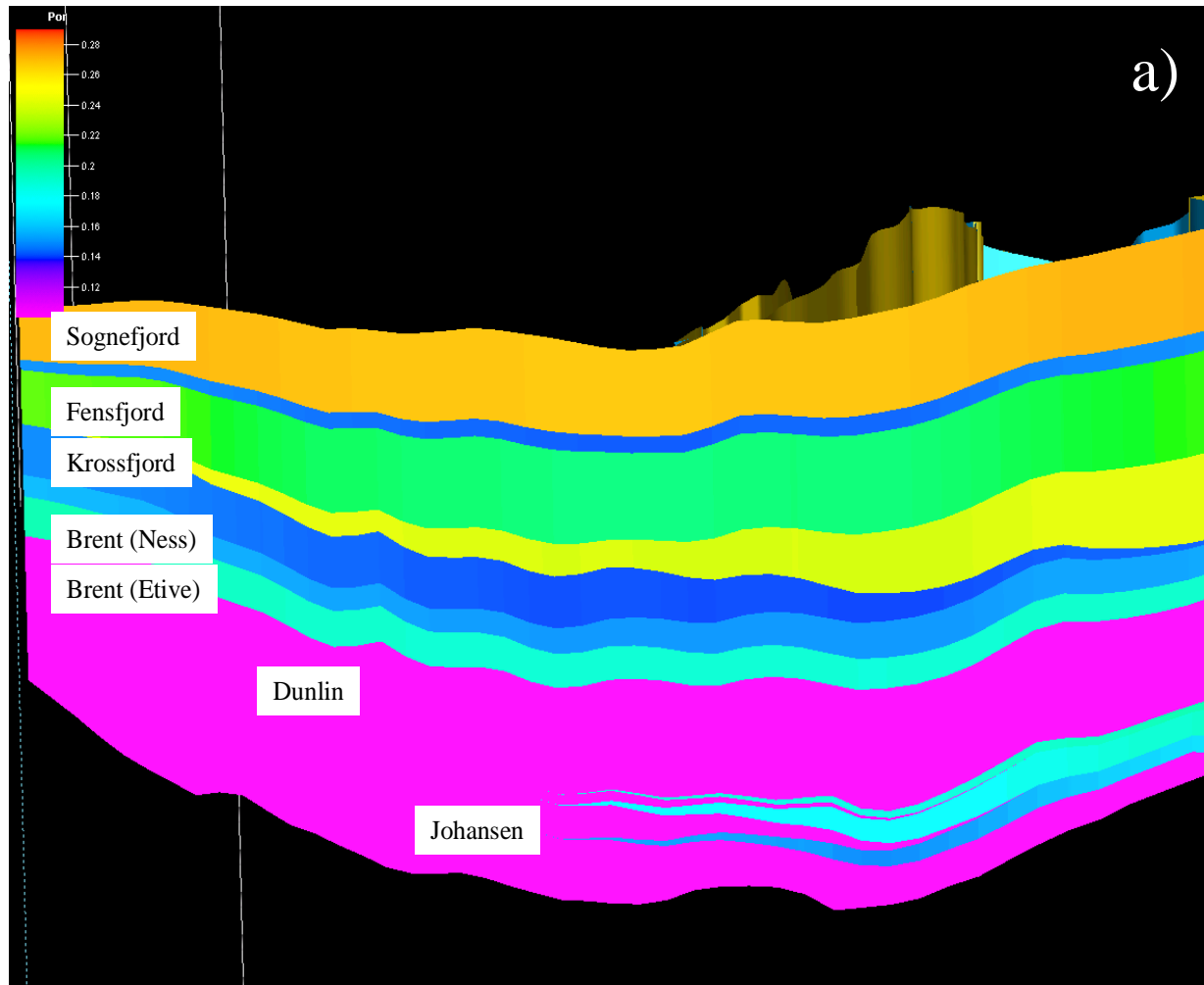
- Further works and mapping for the *Troll – Johansen* was carried out – along with acquisition of 3D seismic data in Block 31/5

*2008 –  
Mid 2009*

- In the Spring of 2009 following the outcome of “konseptvalg 2008” it was decided that GASSNOVA SF should continue the work & projects that the NPD had initiated – in order to further mature the selection of site(s) for permanent CO<sub>2</sub> storage

*Mid 2009 –*

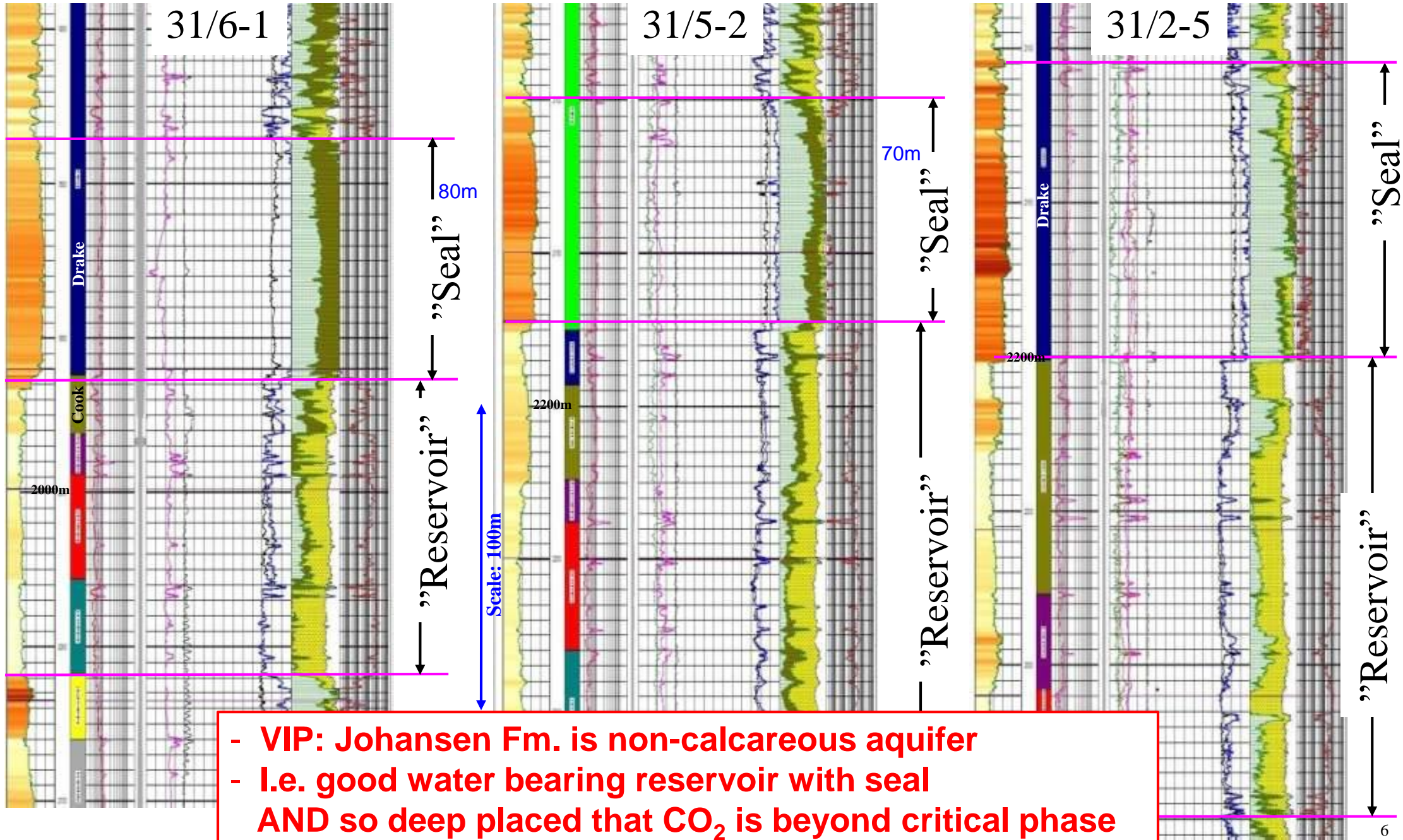
# Johansen Formation & 3D Survey outline



a) Geol. Cross-section showing the relation between the Lower Jurassic Johansen Fm. in relation to the overlying Sognefjord & Fensfjord Fm. from which the Troll Field produces. The interval between these two “targets” is approx. 500m in this area, consisting of several sealing shale layers.

b) Index map of the 3D survey outline (NOCS Block 31/5) in relation to the surrounding Troll Field to the East & North. The thick white dotted line indicates the approx. location of the Geo-profile in a).

# Well info – overview cpi logs

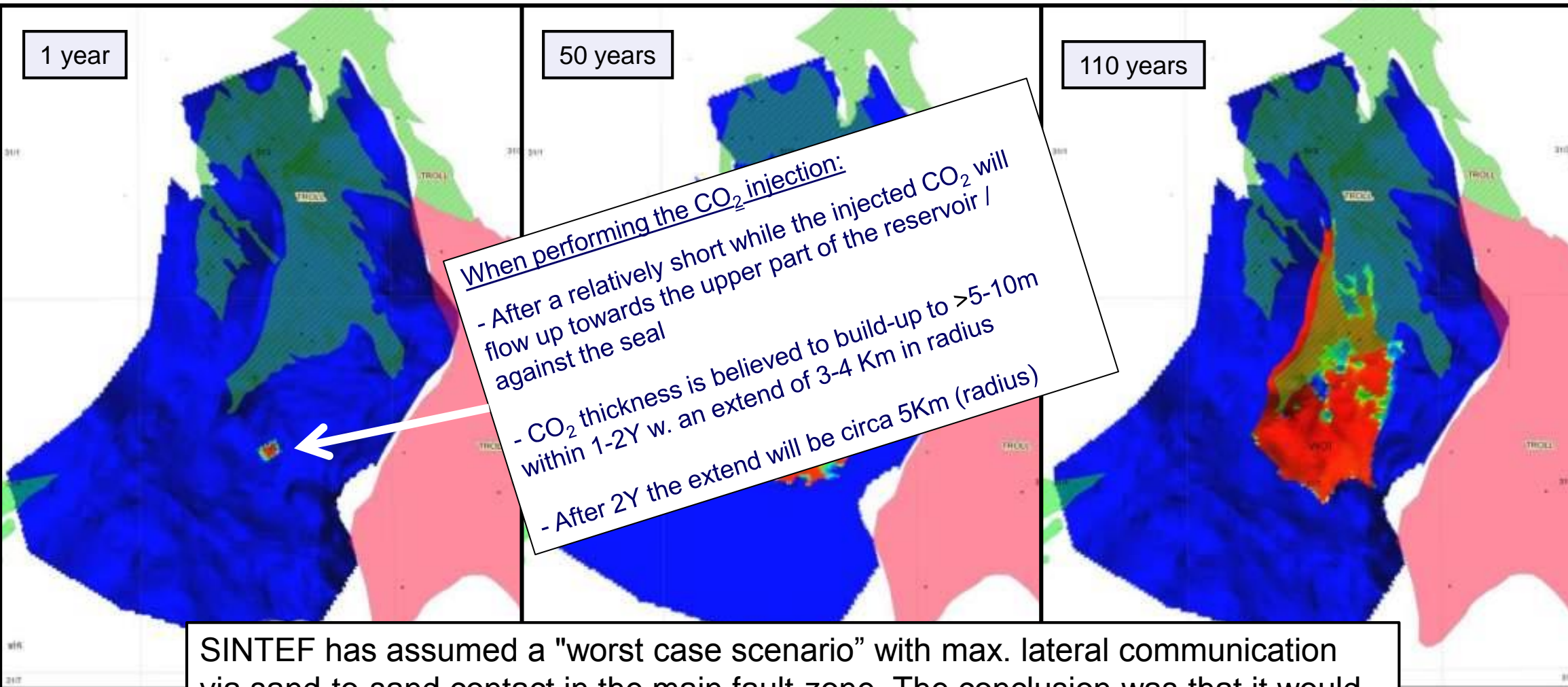


# Result from SINTEF 2007 simulation



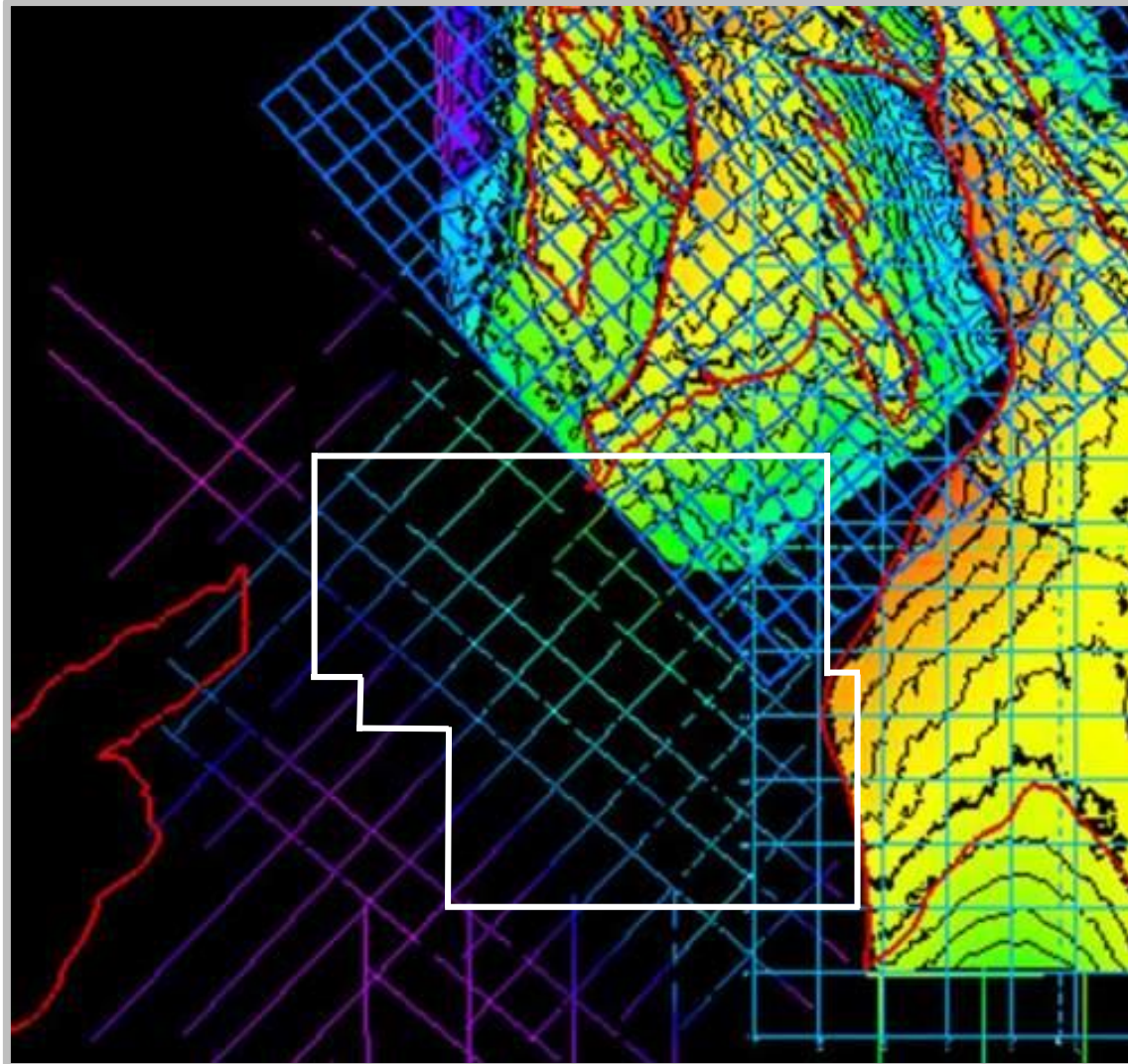
[ This simulation was based on knowledge as before a fault-seal study was performed by Badley's (2008) and the update mapping based on new 3D seismic ]

- Yearly injection-rate 3.0 MT CO<sub>2</sub>



SINTEF has assumed a "worst case scenario" with max. lateral communication via sand-to-sand contact in the main fault-zone. The conclusion was that it would take **at least 150 years** before the CO<sub>2</sub> would reach the Troll reservoir.

# Pre-study, Semi-regional seismic interpretation



3D seismic covering the Troll Field, the remaining study area covered by 2D seismic

Difficult to map the details and limit of the Johansen Fm. towards South and Southeast based only on 2D seismic

In 2008, a new 3D-seismic survey was acquired and processed, providing:

- **Improved reservoir mapping**
- **Better control of faults / fractures**
- **4D Base-line survey (=  $T_0$ )**
- **Optimal placement of verification well**

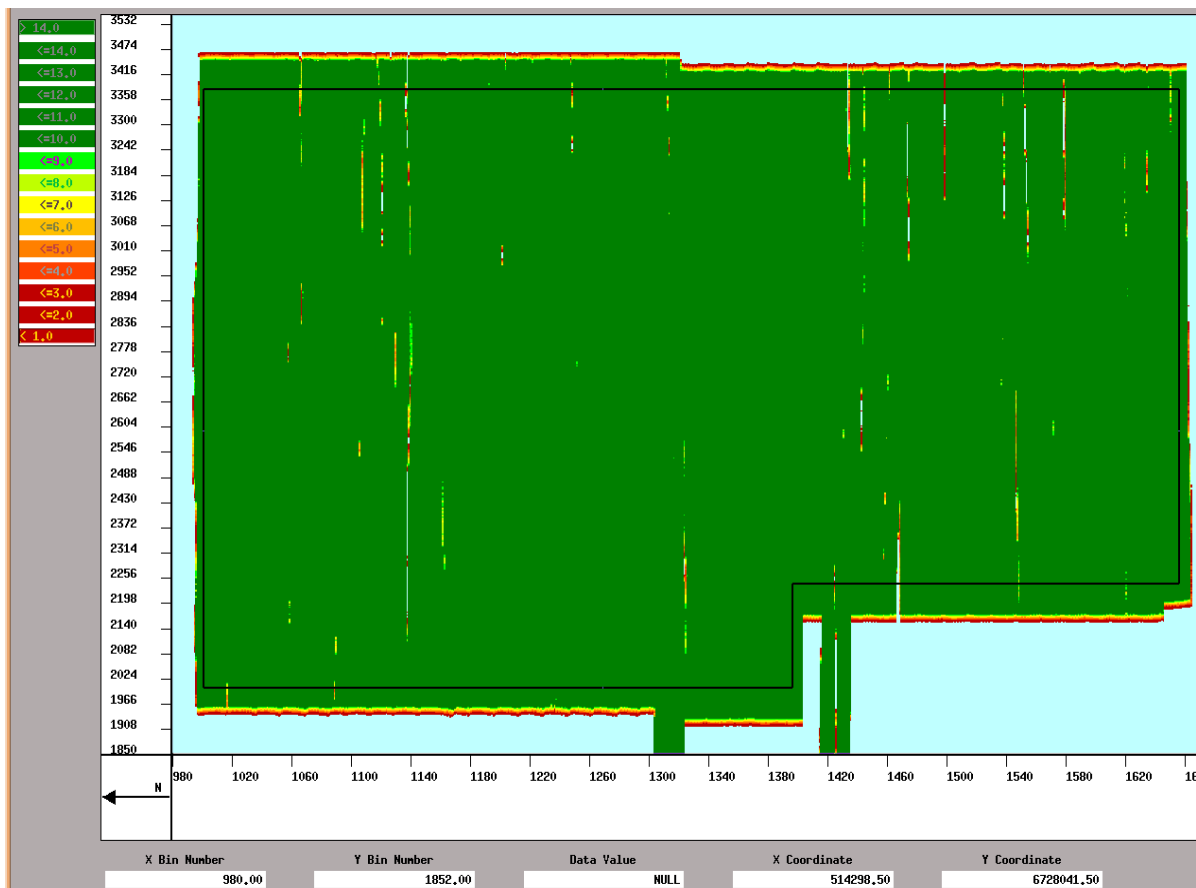


# Data Acquisition & Data Processing

# Seismic Data Acquisition



Coverage Plot, Far-mids.



## Parameters:

Survey vessel: PGS RAMFORM CHALLENGER

Period: 4 - 17 Sept. 2008

10 streamers @ nominal 7.0 m depth

(1 streamer overlap to next pass = "4D Ready")

Active streamer(s) length – 3000 m

(Need of this offset 80-85% at 2,5 sec. TWT)

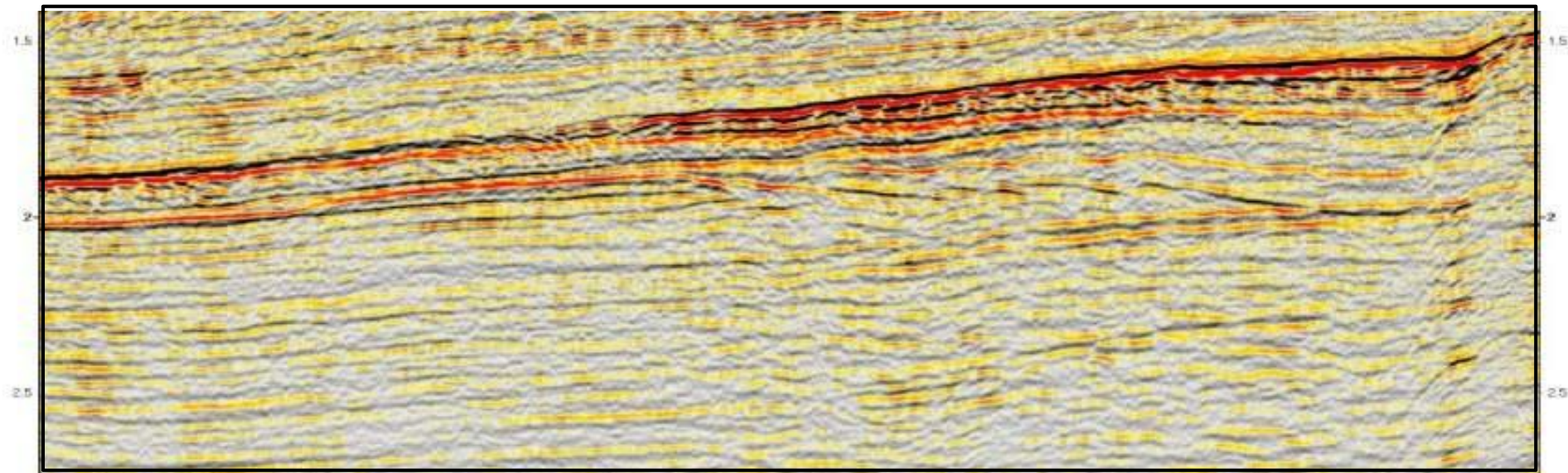
Flip-flop shooting, 12.5 m pop interval – 60 fold

4096 ms recording length

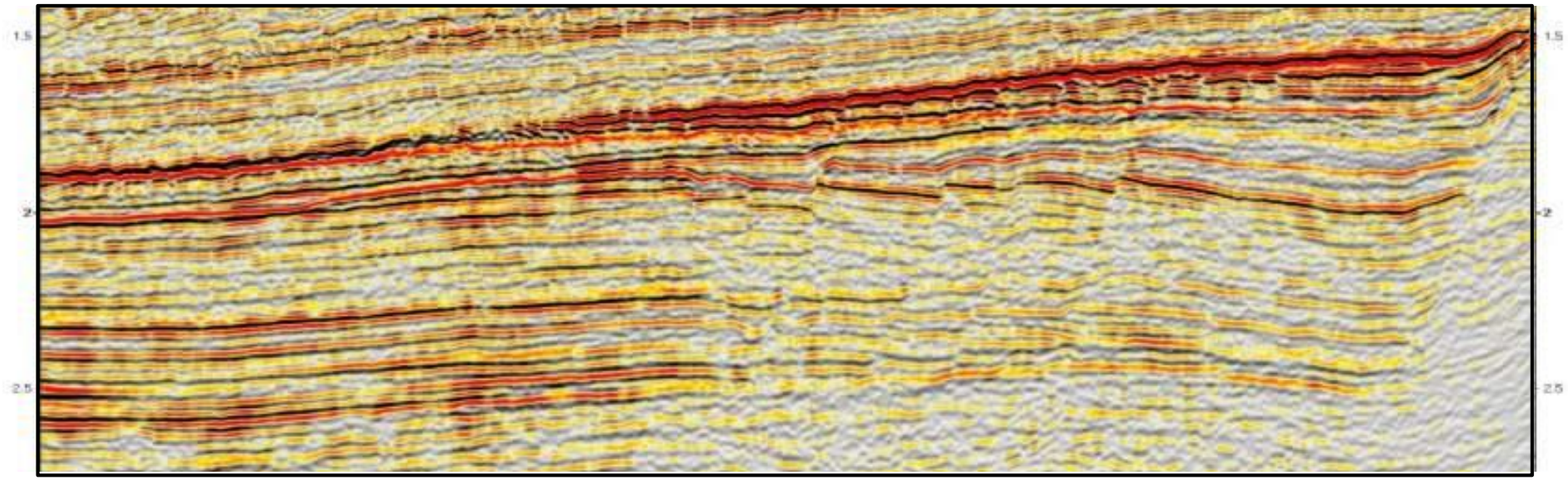
Survey volume:

300 km<sup>2</sup> FF; infill was 3.4 %

# Inline 1221: Stack before De-multiple, no SRME (& no Radon)

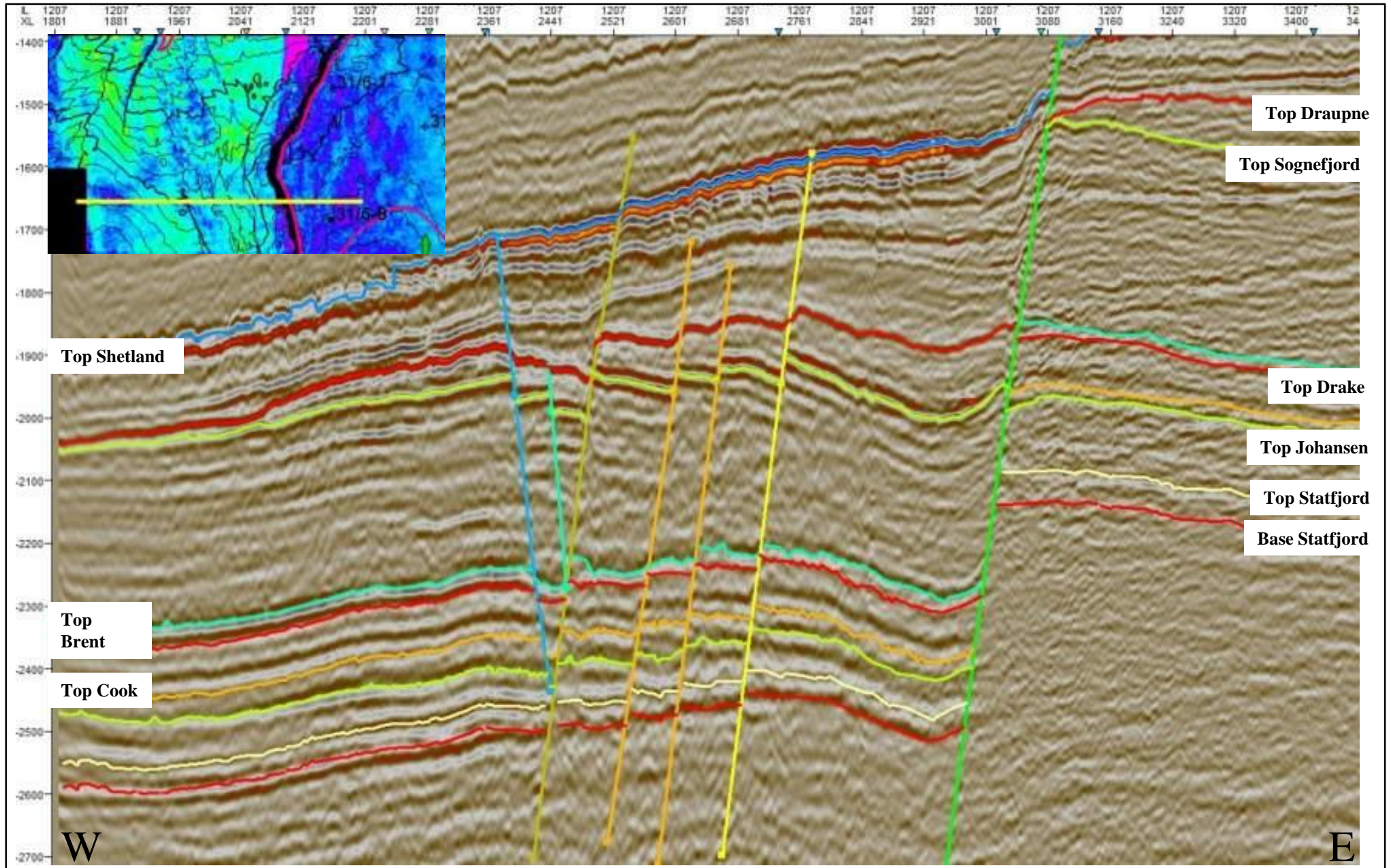


# Inline 1221: PSTM Stack

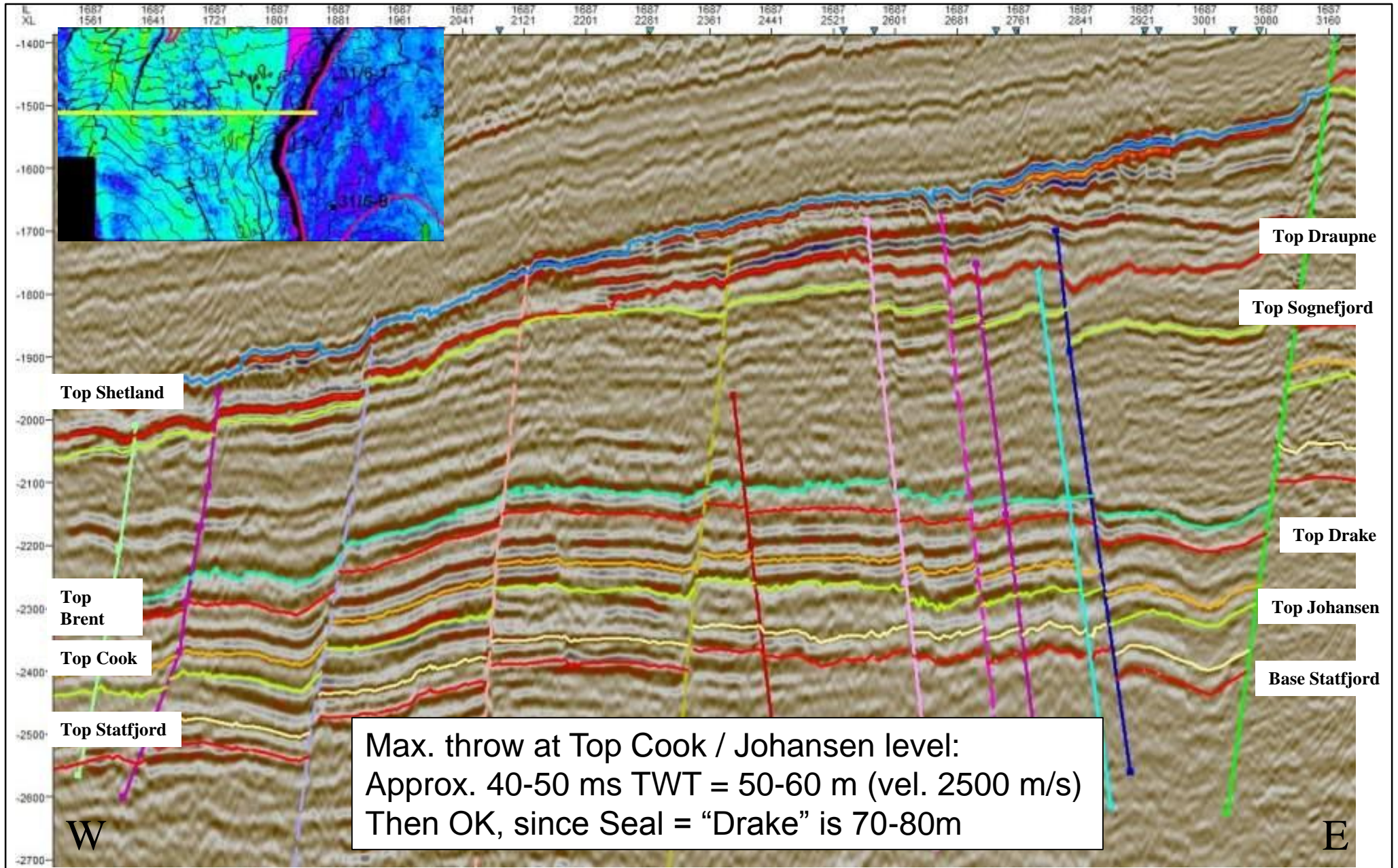


# Results / Mapping of the Johansen Formation in Block 31/5

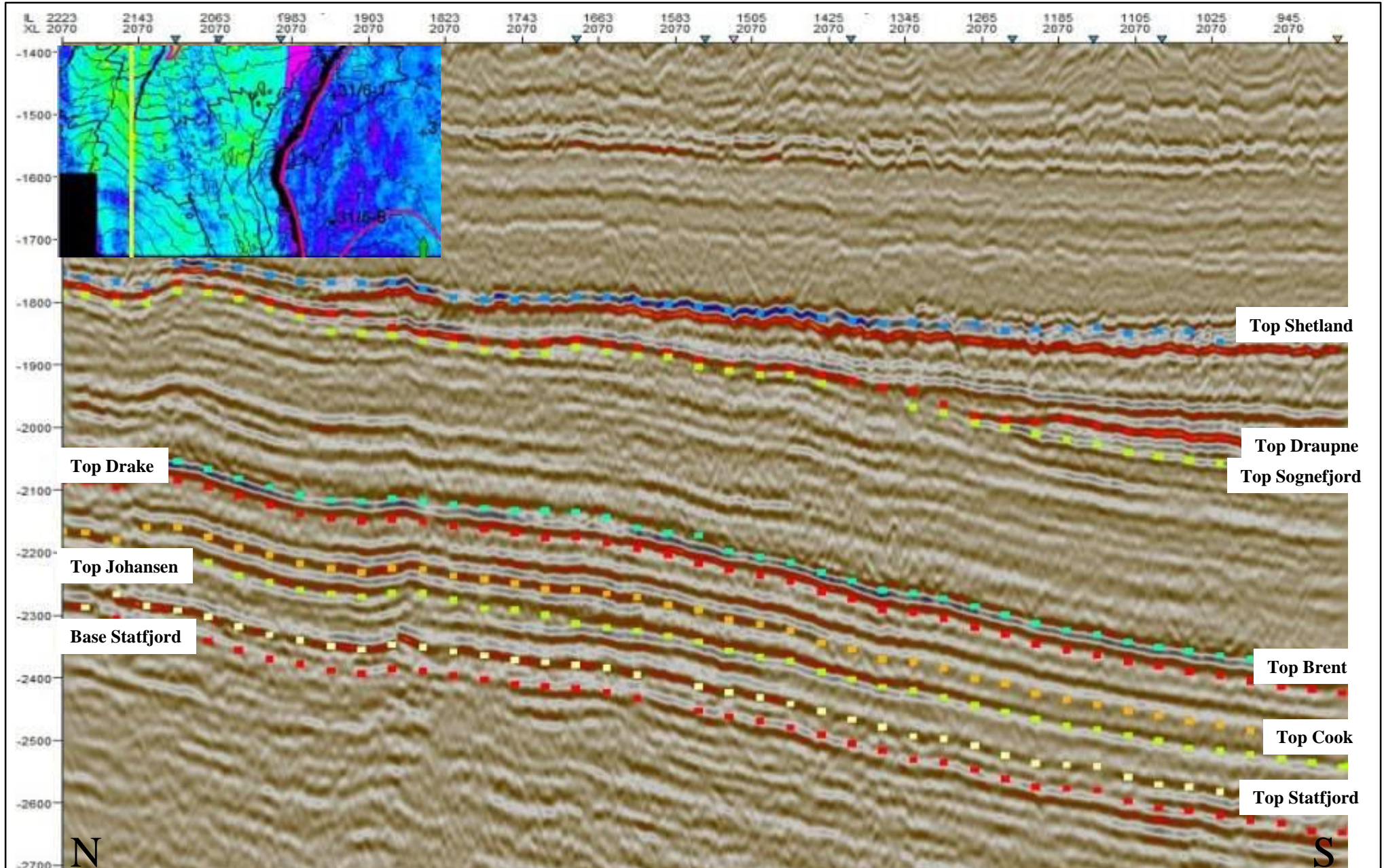
# Inline 1207



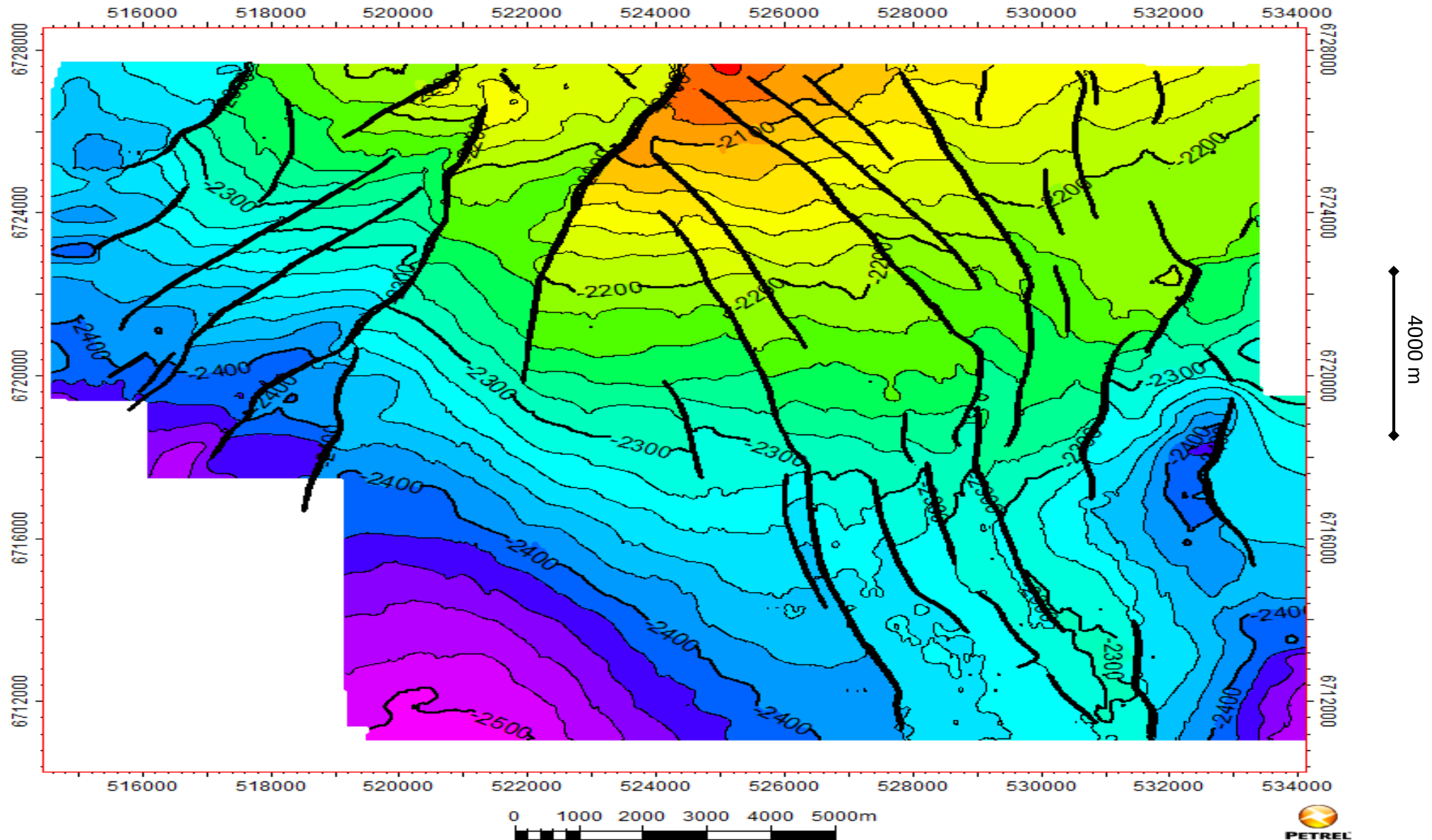
# Inline 1687



# Crossline 1399

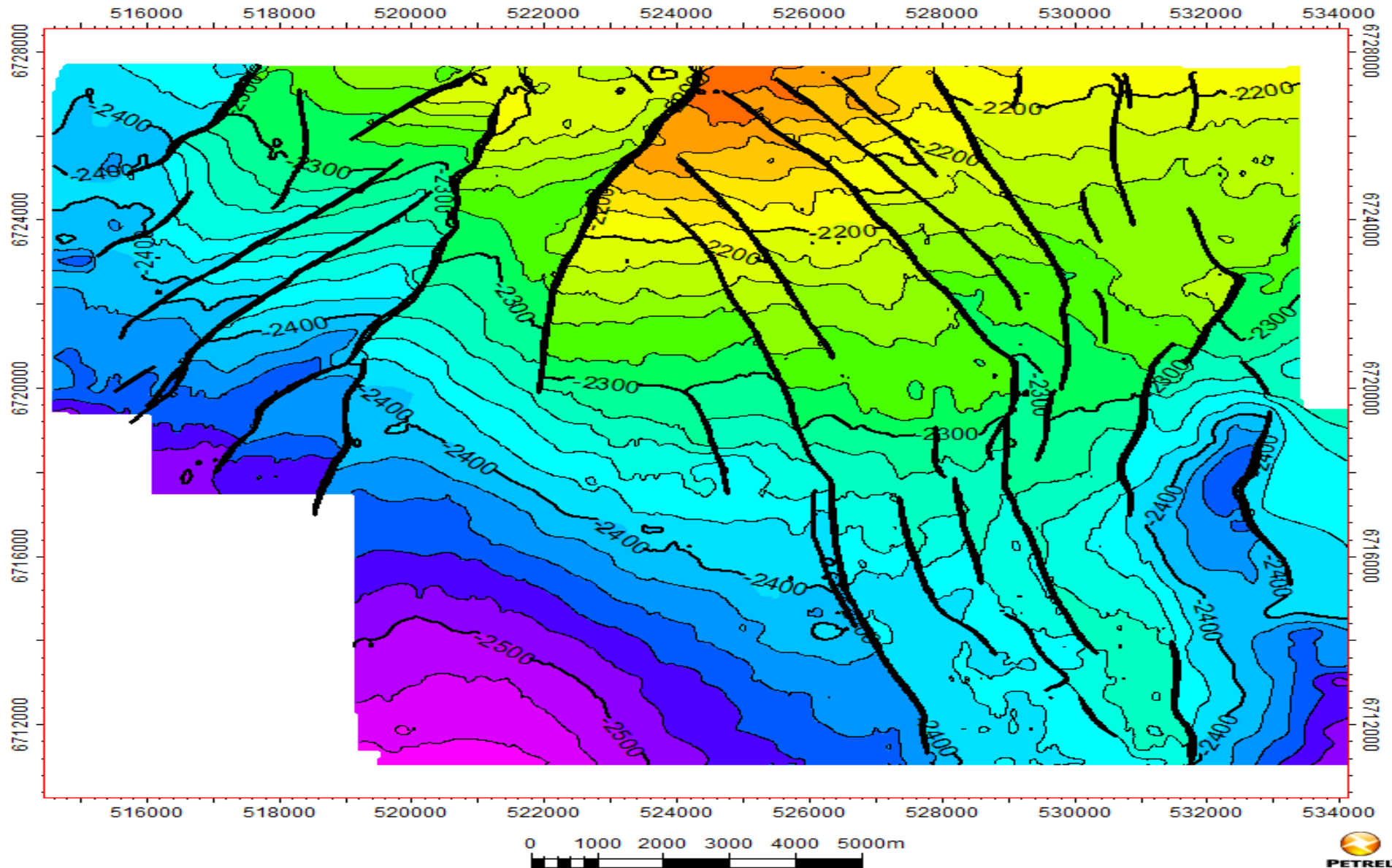


# Top Cook Time-structure

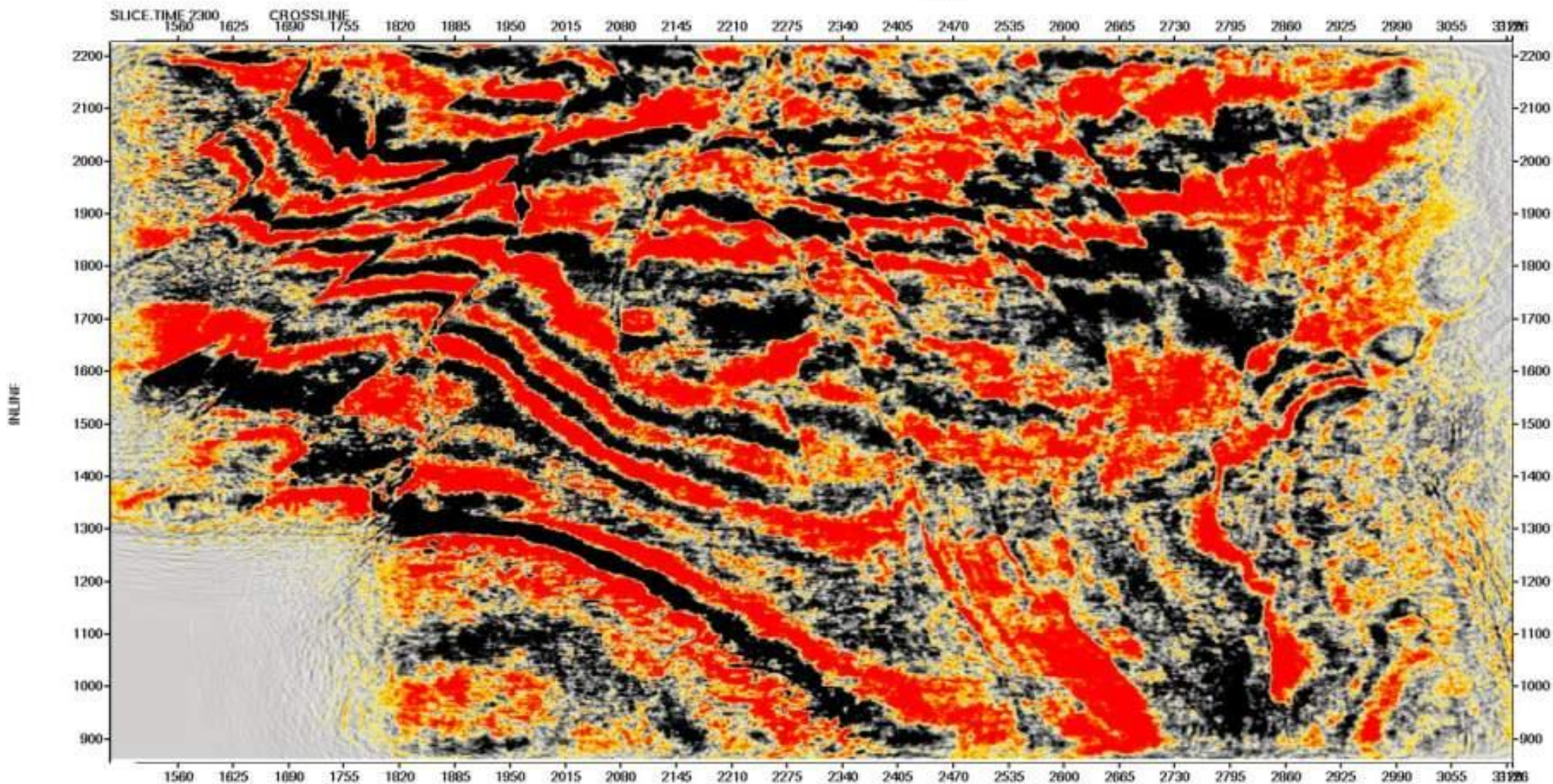




# Top Johansen Time-structure



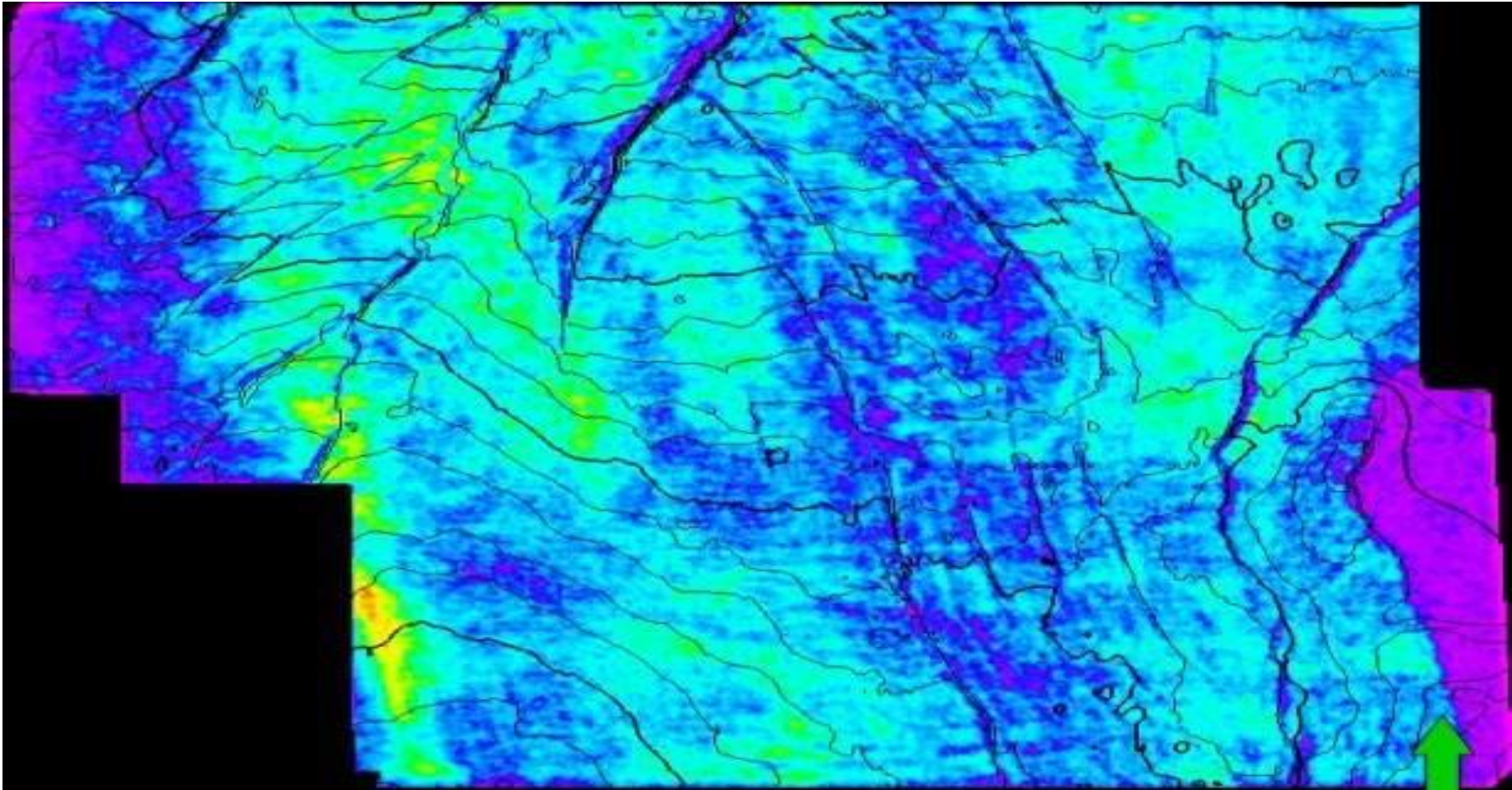
# Time slice at 2300 ms



Time Slice at 2300 ms, close to the 'zone of interest'

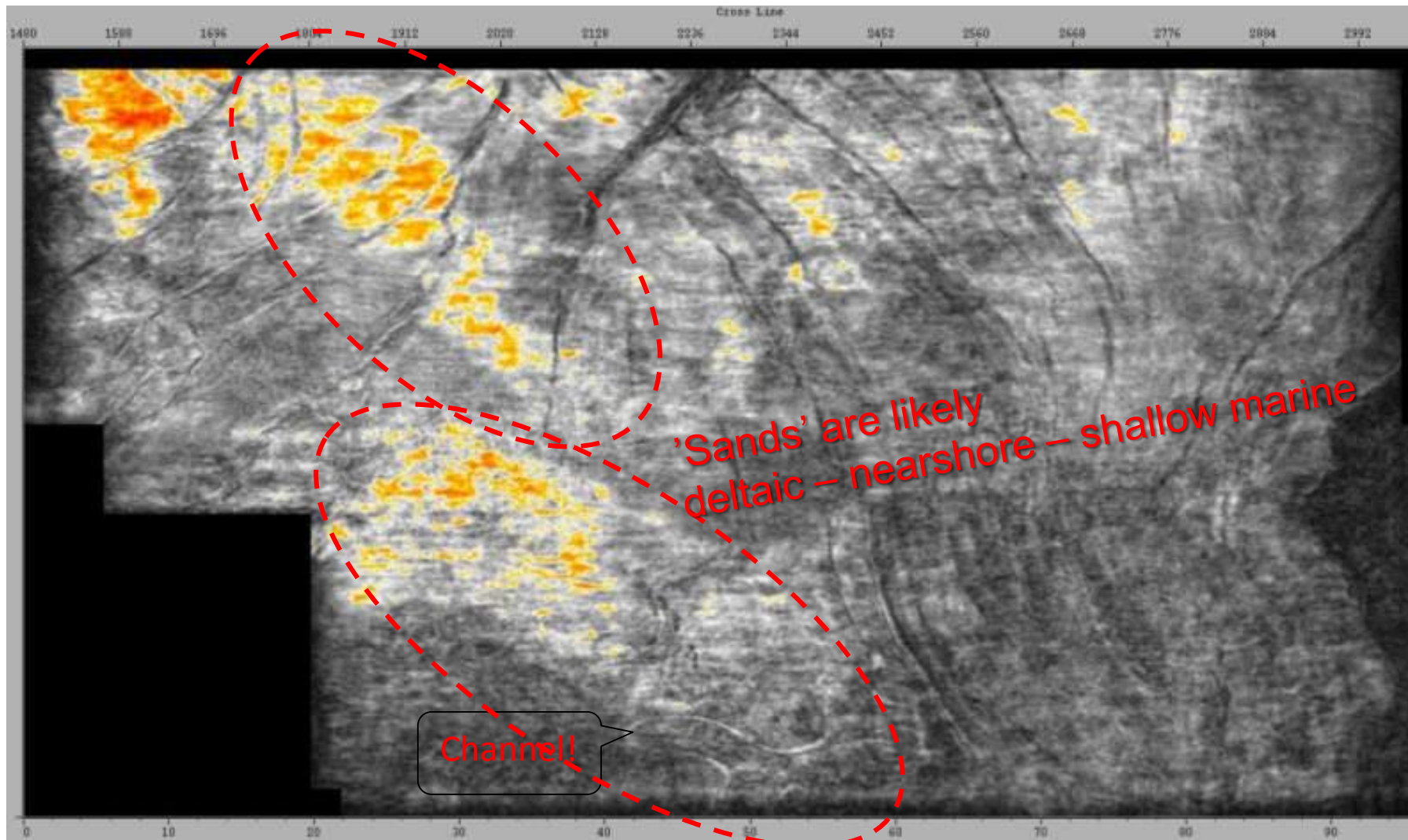
# Johansen Relative Acoustic Impedance (RMS Amplitude)

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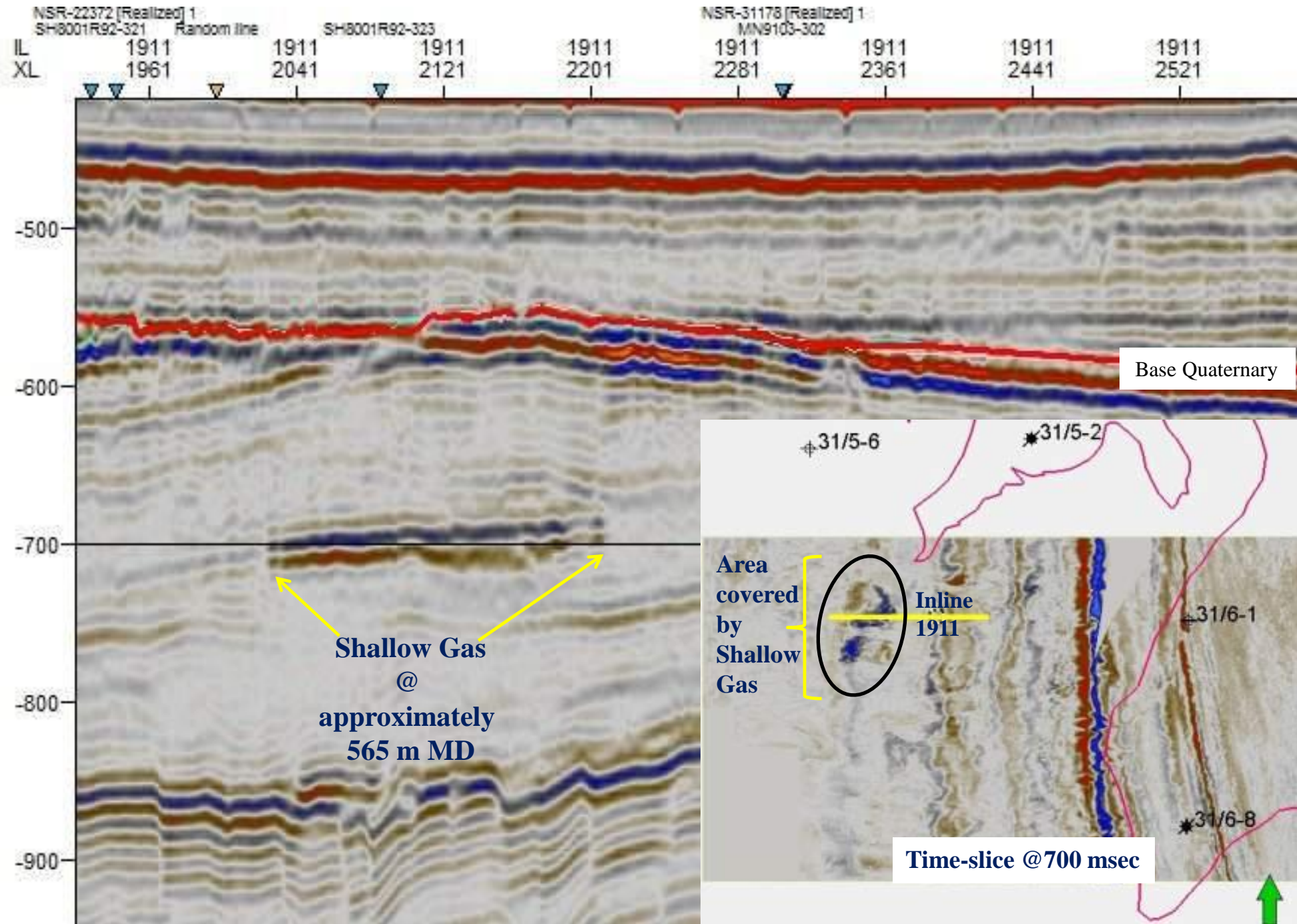
Petrel Tool: Estimated relative acoustic impedance is calculated by integrating the trace, then passing the result through a high-pass Butterworth filter

## Thin Slab Slice (100ms) at 2220ms



'Thin Slab Slice' of 100 ms width centered around 2220 ms – providing a very good picture of the fractures / fault pattern at the 'interest zone'. Also observe that a meandering channel to the South in the survey area is revealed.

# Inline 1911



# 4D Sensitivity

# 4D Sensitivity Study

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Purpose: To estimate the 4D effect that can be expected after injection of CO<sub>2</sub> in the Johansen Fm.

The analysis was done on 3 wells 31/6-1, 31/5-2 and 31/2-5 using V<sub>p</sub> and density logs.

Since the wells were outside the area of the interest, the Johansen formation was on the different depth than required. Therefore, the wells had to be shifted to the modelling depth prior to the 4D analysis (2000m +500m for well 31/6-1).

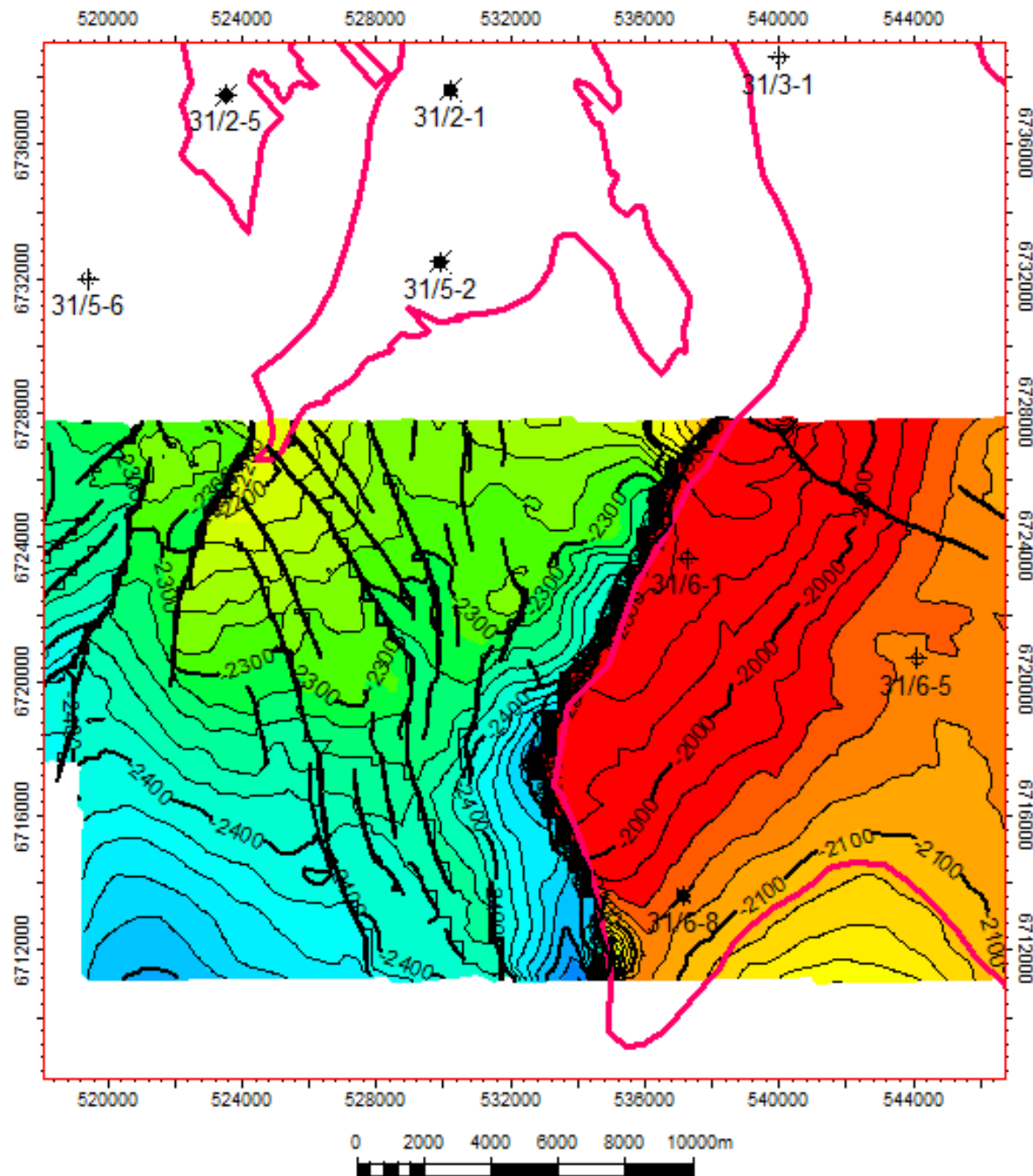
The 4D modelling itself was done for 4 different scenarios:

- CO<sub>2</sub> saturation 90%, CO<sub>2</sub> thicknesses of 40, 25, 10 & 5m

## Main Modelling Steps:

- Moving well to the correct depth
- Fluid substitution scenarios
- Synthetic creation (cmp gathers)
- 4D analysis

# Top Johansen Depth Map





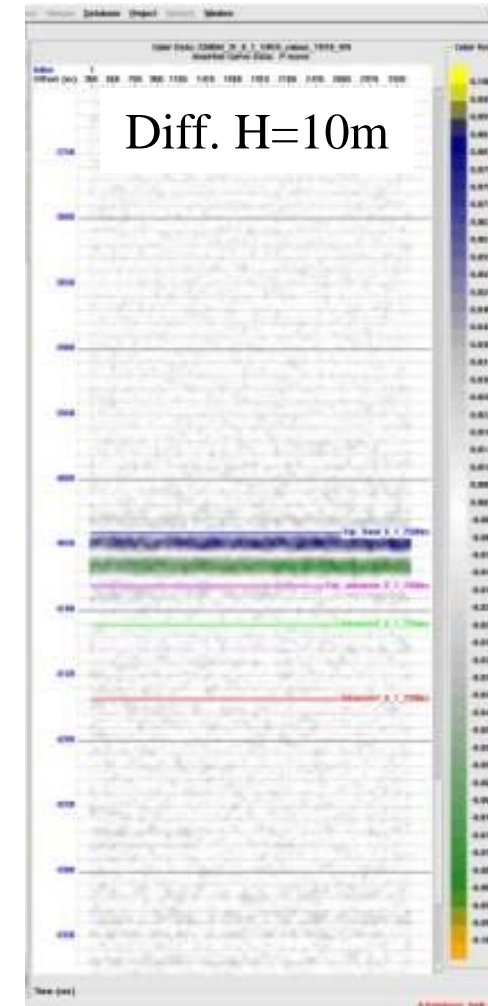
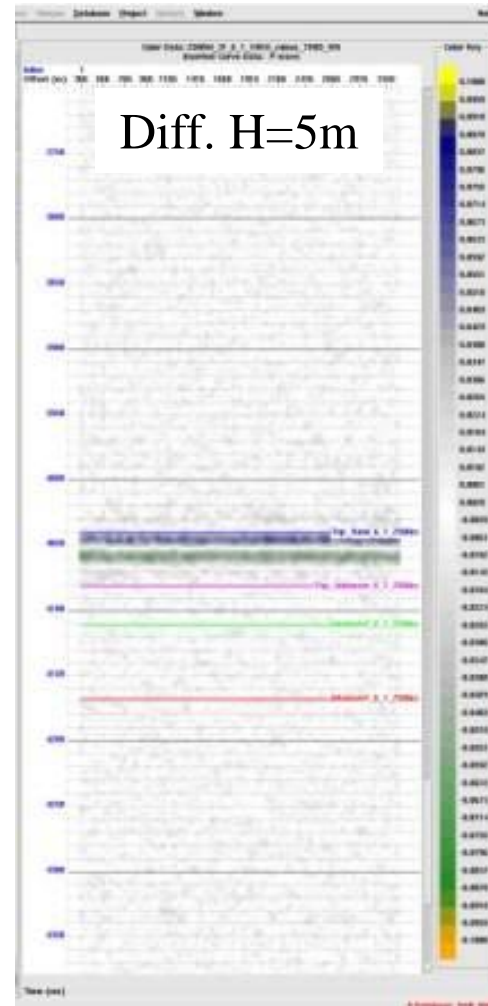
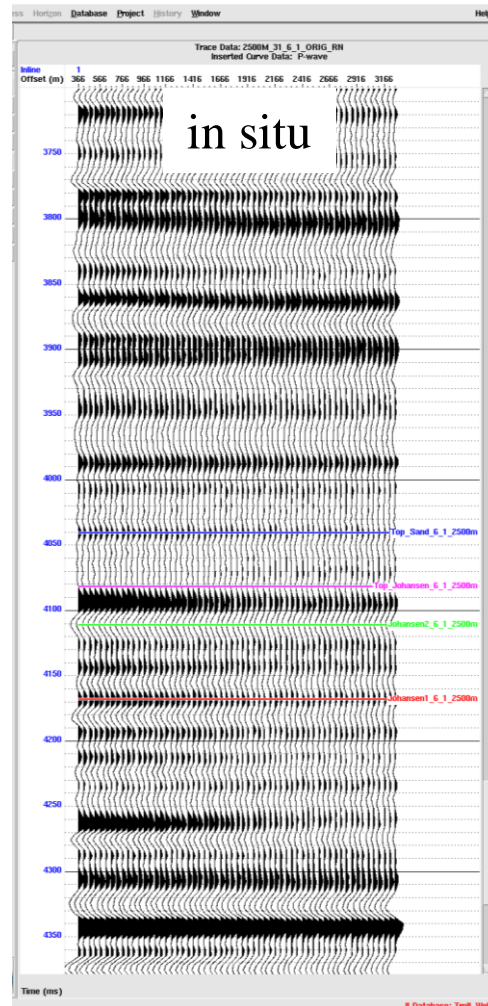








# Well 31/6-1 (at 2500m) – 4D differences (random noise added) before & after CO<sub>2</sub> injection (S<sub>g</sub>=90%; H=5m vs 10m)



**Top Sand**  
**Top Johansen**  
**Johansen\_2**  
**Johansen\_1**

Result from 4D forw. modeling. This was done by using the acoustic impedance from neighboring Block 31/6-1 well and “projecting” the logs at +500 m depth (in order to best simulate conditions at Block 31/5). A ‘realistic’ CO<sub>2</sub> saturation of 90% was used and several thicknesses were modeled. Herein, the expected seismic 4D responses for CO<sub>2</sub> column thickness of 5 & 10 meters are shown.

# Conclusions / Recommendations

## Conclusions / Recommendations

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- ◆ A 3D dataset of good quality has been obtained  
- in order to make a decision for a pilot well location
- ◆ T<sub>1</sub> monitor survey should be acquired after circa 2 years of CO<sub>2</sub> injection  
[ based on assumed flow-rate of 3.0Mill.T per year ]
- ◆ In general: We can capitalize on the experiences gained for hydrocarbon reservoirs - and use very similar methodologies in order to best manage CO<sub>2</sub> storage projects

# Acknowledgements

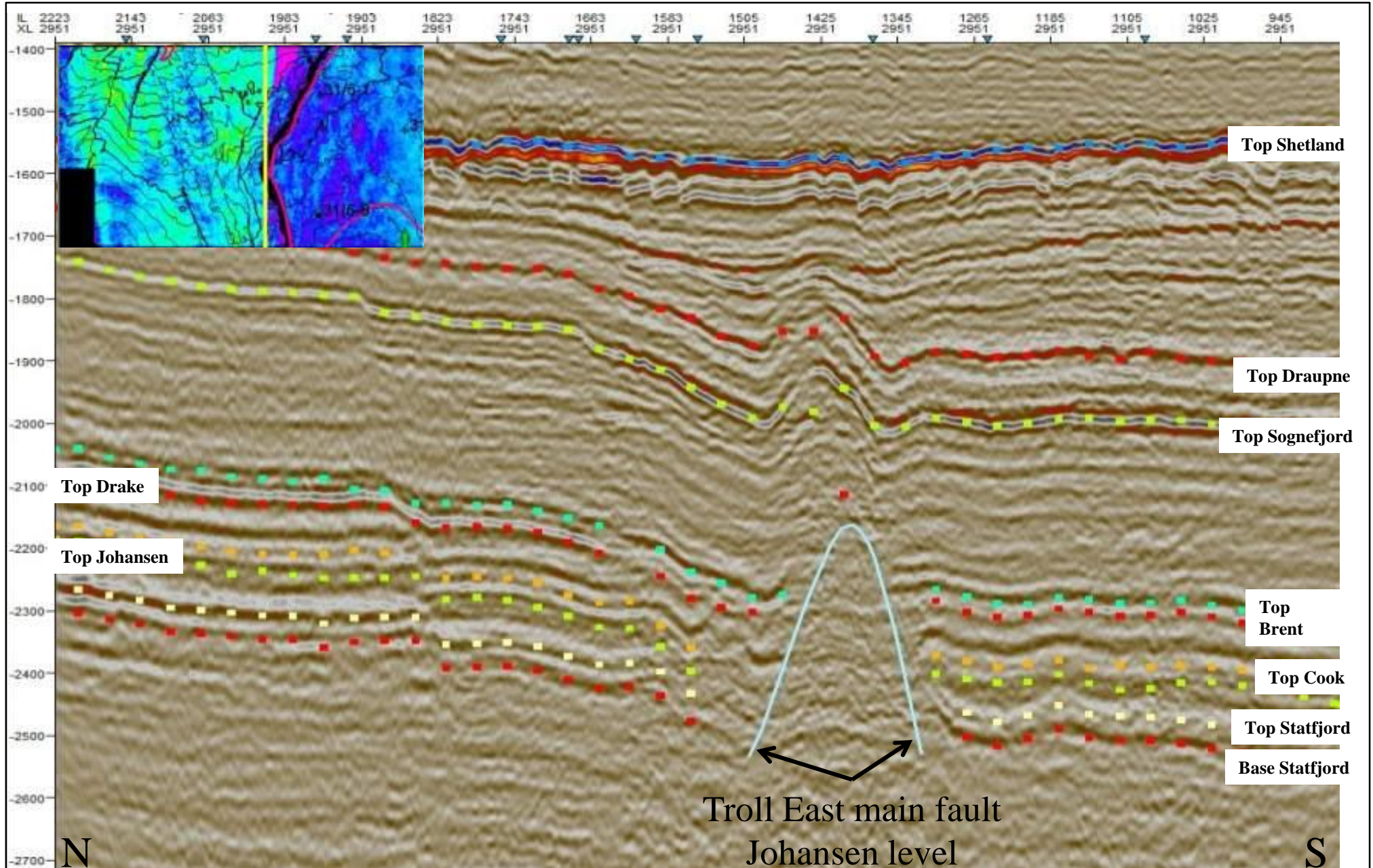
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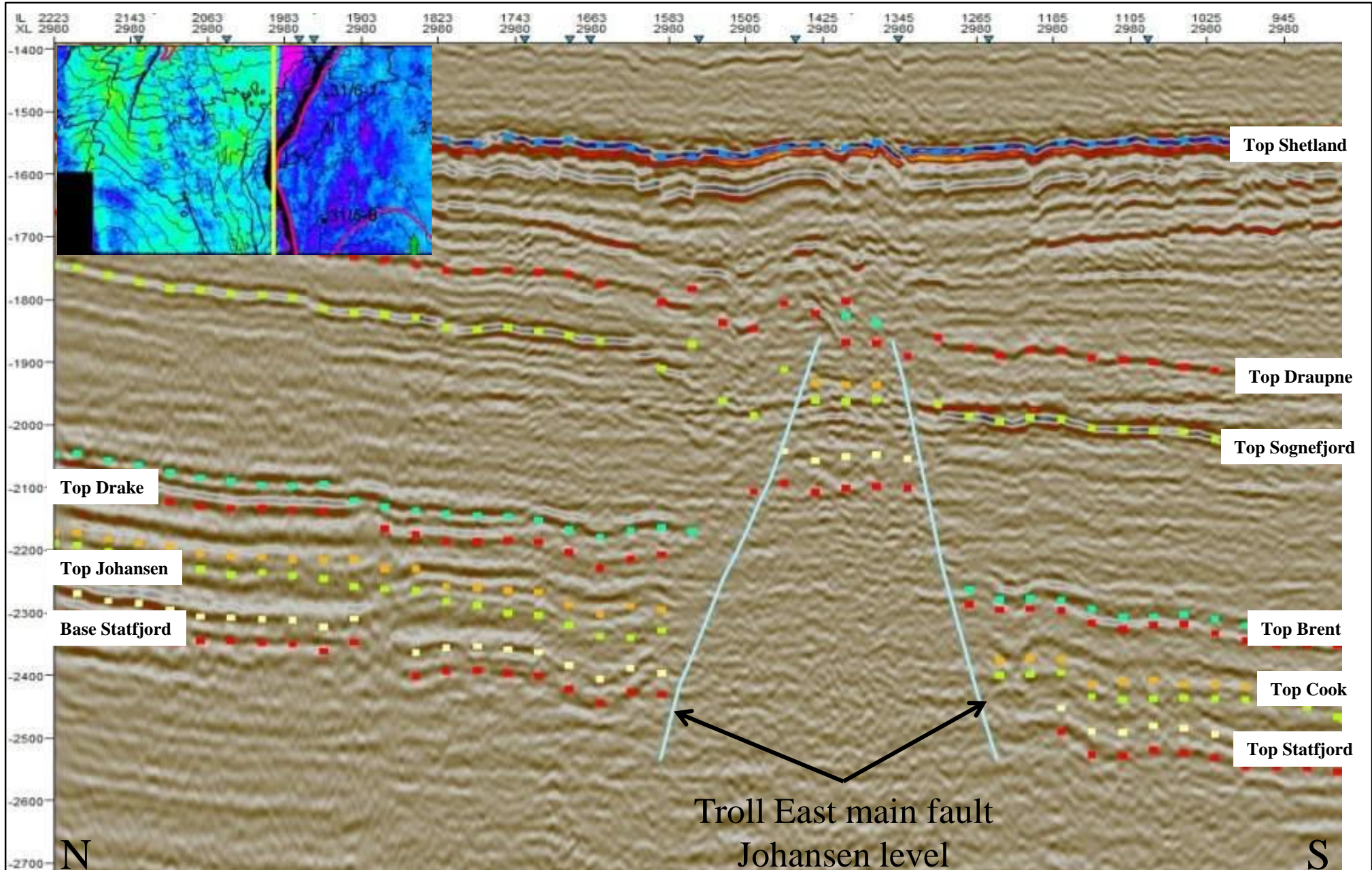


MISC SUBJECT:  
"Drag folds" along the main  
Boundaring fault towards  
Troll East

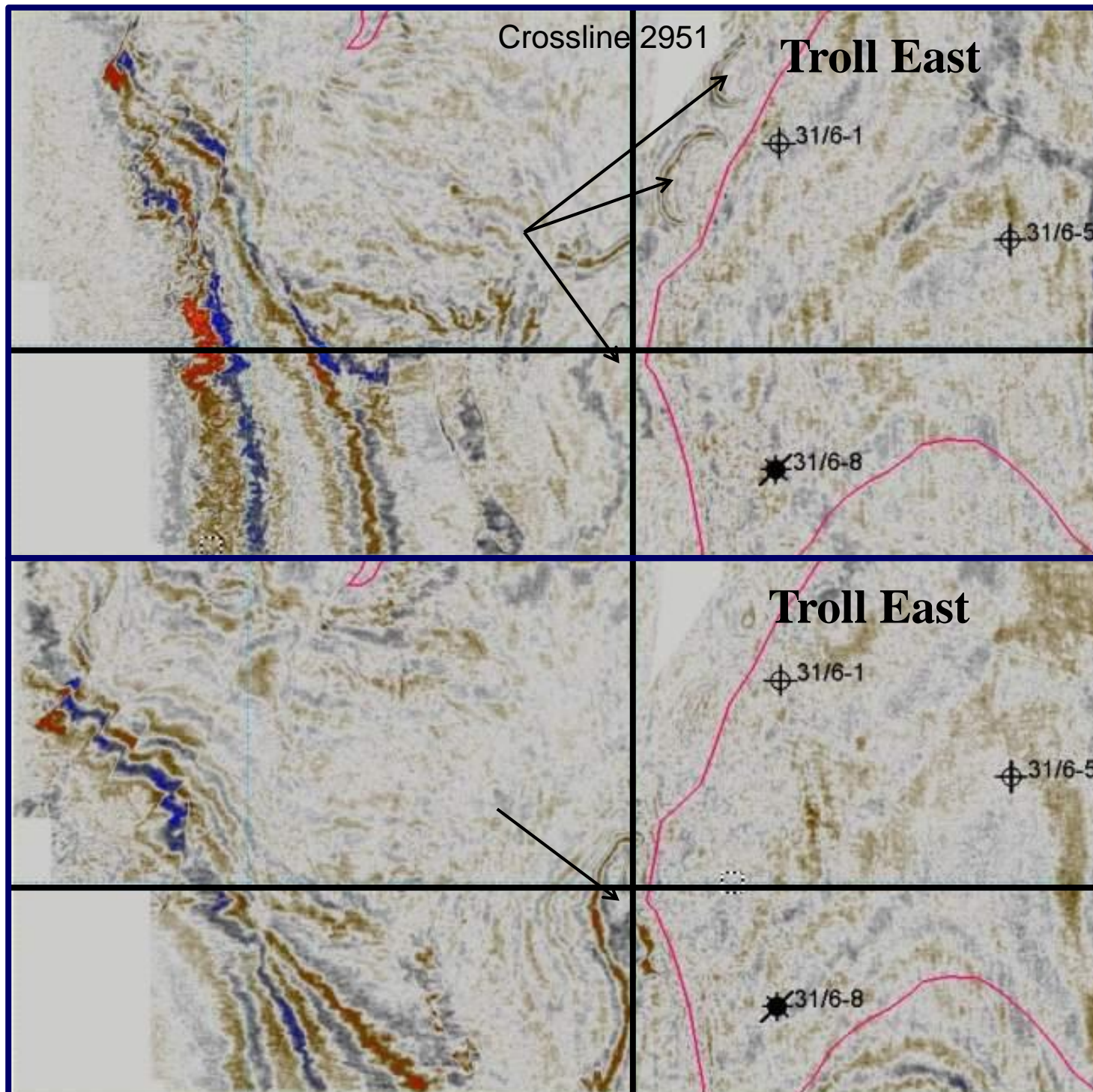
# Crossline 2951



# Crossline 2980



# Drag effects along Troll East Border Fault



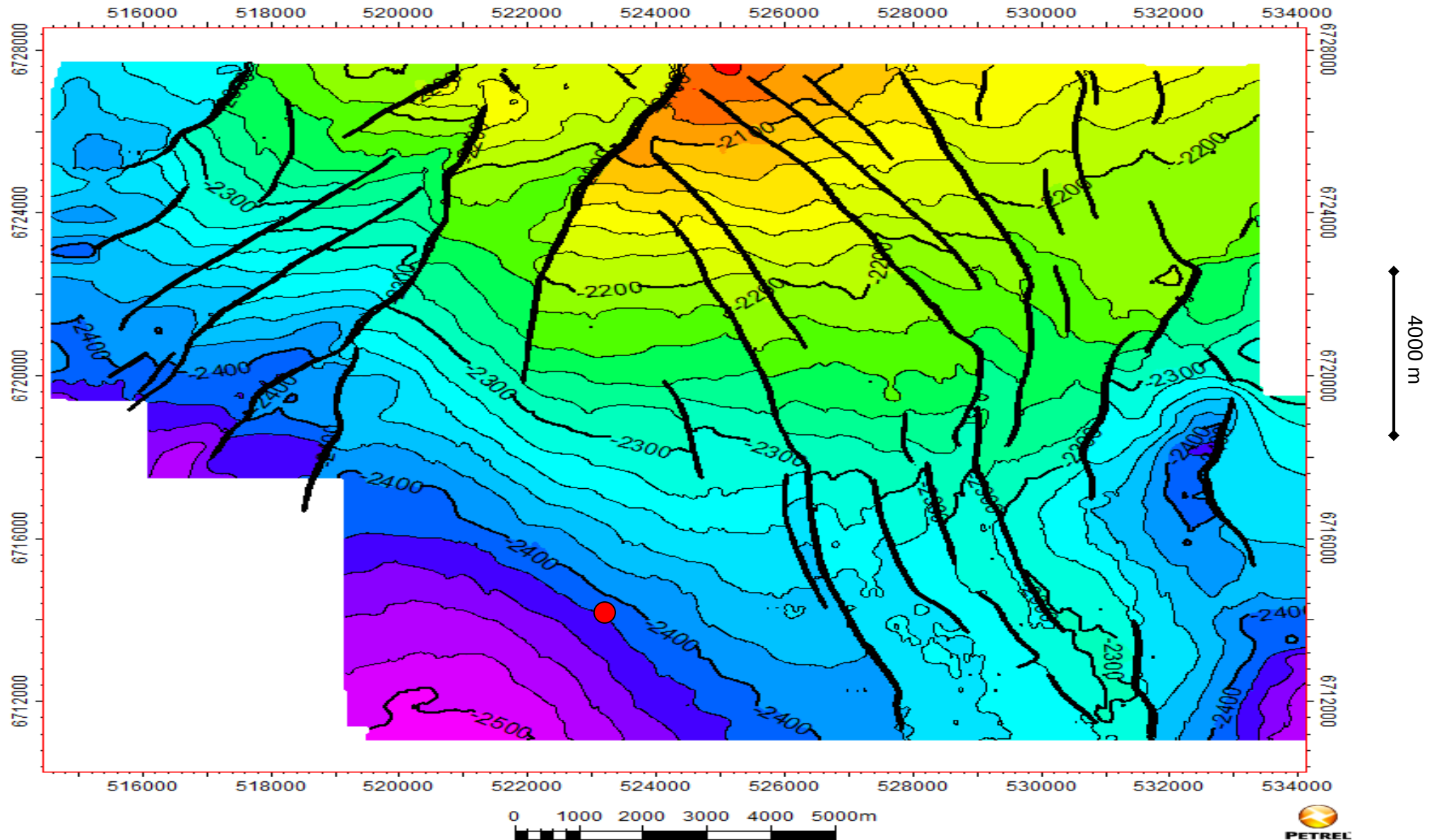
Timeslice 1878 ms

Inline 1399

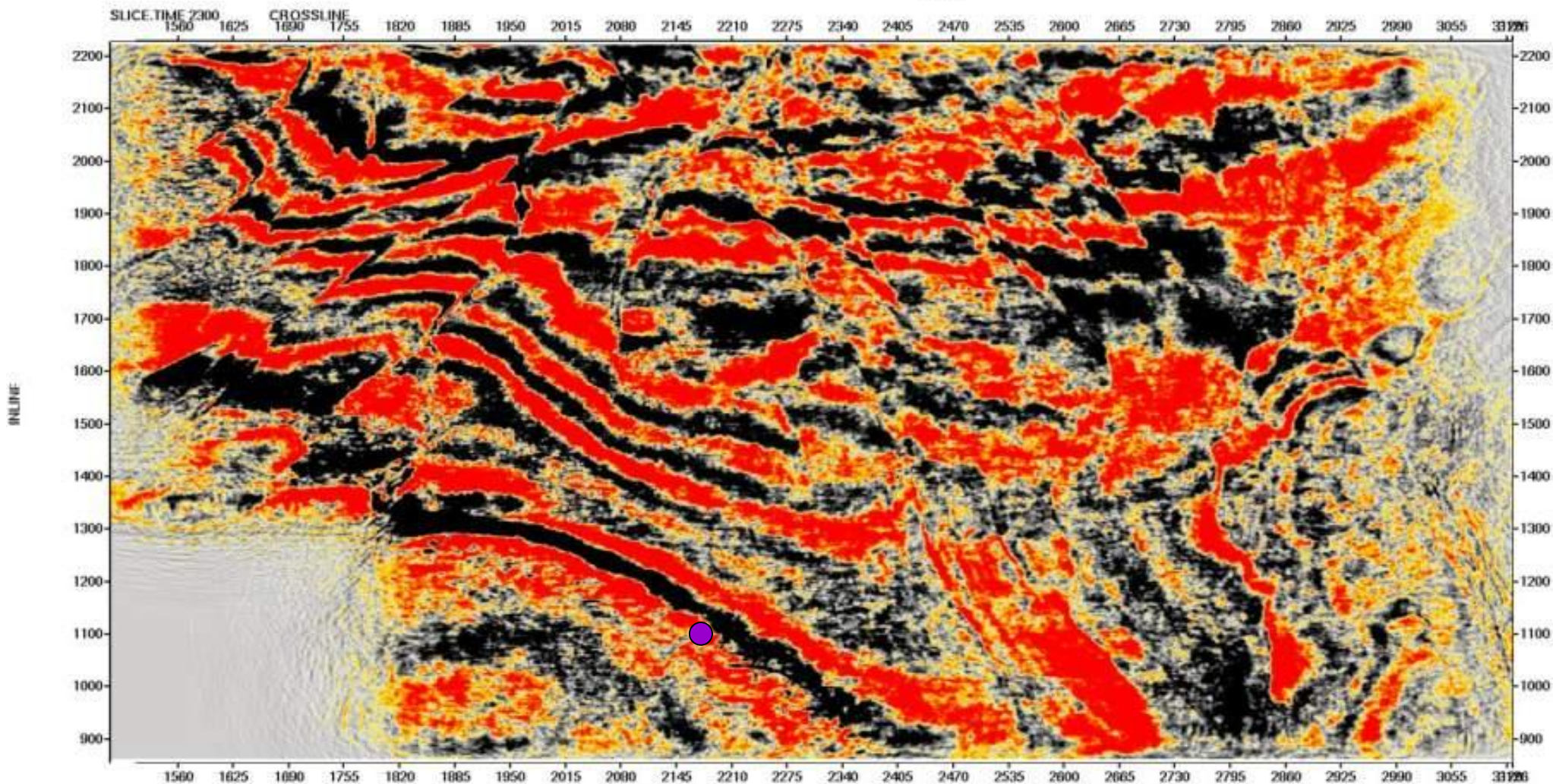
Timeslice 1988 ms

Inline 1399

# Top Cook Time-structure



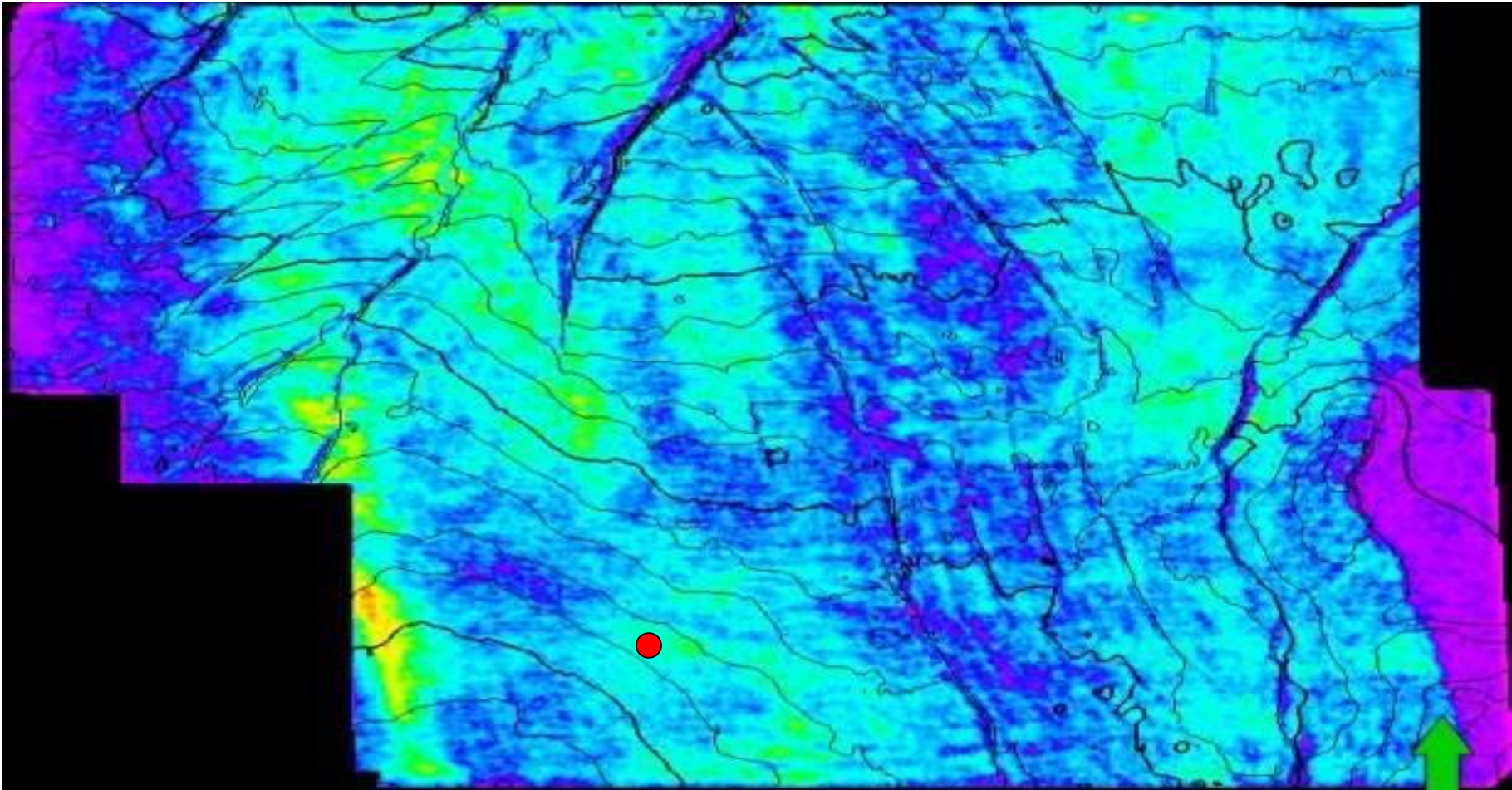
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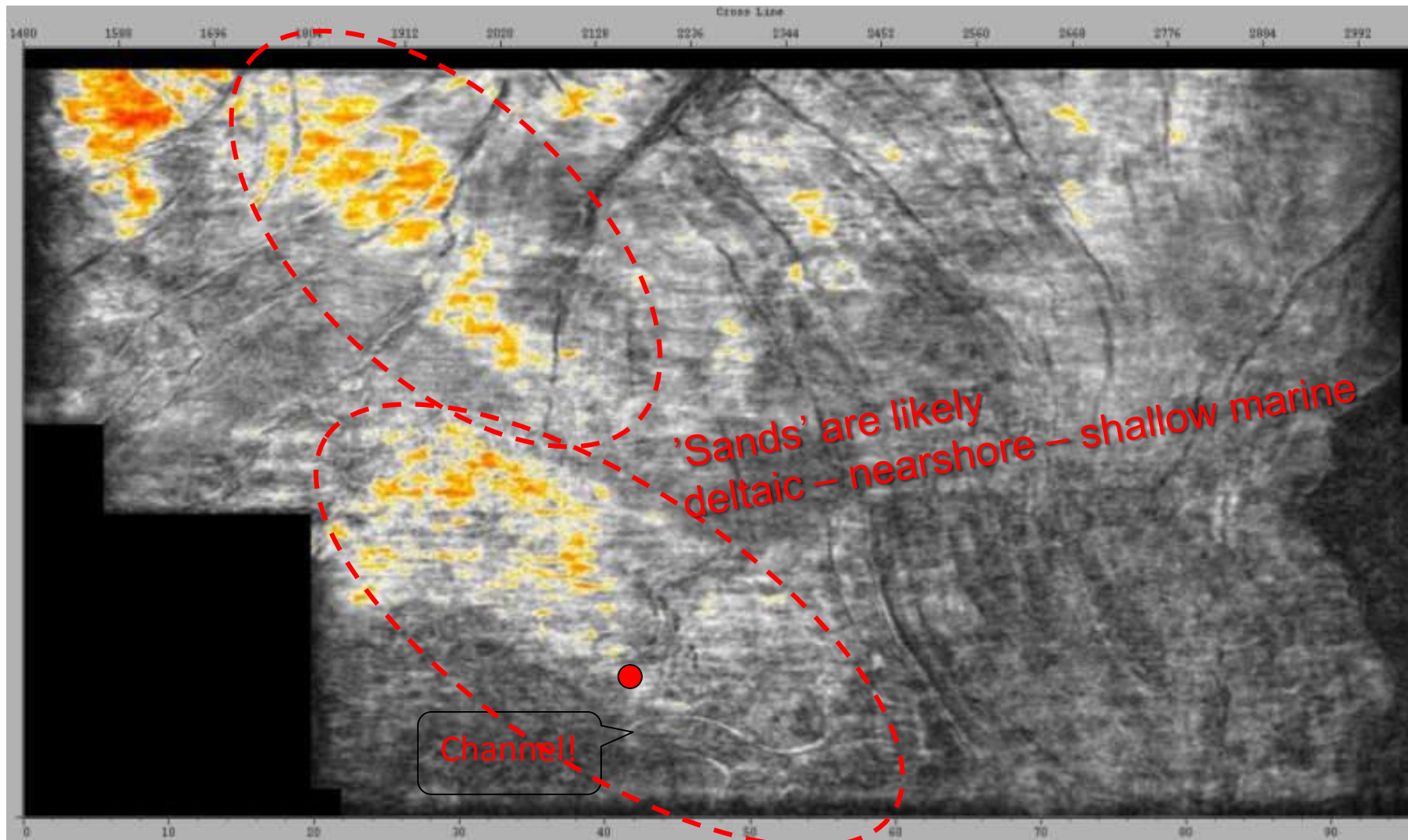
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