Atlantic Margin, Stratigraphic Play: An Integrated CSEM-Seismic Approach to De-Risk Fluids?*

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Abstract

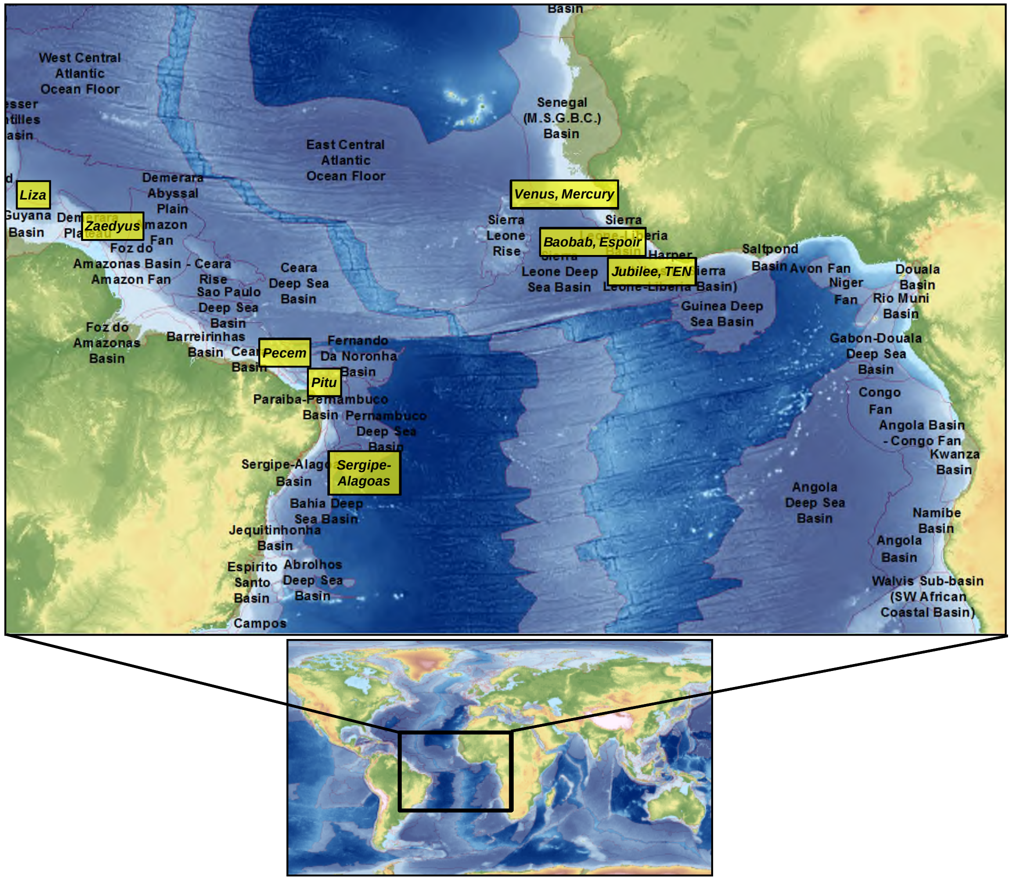
In 2013 during the latest offshore exploration bid round the oil giant TOTAL was awarded the operatorship of 5 deep water exploration blocks of total 3800 km^2 located in the Atlantic margin. TOTAL has signed high commitments including large 3D seismic acquisition and high number of wells drilling program for next 5 years. Given basin is remaining underexplored due to the remoteness of the area and poor exploration results up to now (only 10 shelf wells with HC traces). The working petroleum system of the basin was proved by Shell's recent drilling campaign in the neighbour country to the North. From the current evaluation, the considered exploration blocks represent 4 Gboe of unrisked mean resources for TOTAL. Depth processing project of large 3D broadband seismic multi-client campaign (more than 11,000 km^2) was terminated only in December 2015. It enabled a definition of large variety of plays dominated by upcurrent stratigraphic trapping in the Upper Cretaceous. There are massive reservoir sands concentrated inside large multi-storey turbiditic channel complexes in the middle slope sealed by overpressured shales. Trapping mechanism is explained by having a by-pass in the upper slope; fairways are shale plugged during highstand. The AVO and rock physics studies have played an important role in the prospect interpretation. The available 3D seismic data is an excellent lithological indicator, allowing mapping of sands. Nevertheless, mineral content of reservoirs, burial, specific petrophysical parameters and high fluid pressure make the Upper Cretaceous reservoirs the Class I AVO sands without a fluid effect from the seismic data (calibration from offset wells). In de-risking fluid content, EMGS 3D CSEM 3,600 km^2 dataset was licensed (acquired as multi-client survey in 2013). A confident start model (2.5D, 3D unconstrained and constrained) has been created after tens of iterations through the proprietary inversion project (2015-2016). Different inversion results were largely challenged by asset team providing finally set of robust resistive anomalies potentially related to HC presence in the target interval. When the AVO is not a fluid indicator, the CSEM technology in some circumstances when calibrated can be used as a potential DHI. However, it requires high level of geological integration by the operator from inversion to interpretation stages. A case study of a CSEM anomaly supported prospect will be described.

TOTAL

ATLANTIC MARGIN, STRATIGRAPHIC PLAY: AN INTEGRATED CSEM-SEISMIC APPROACH TO DE-RISK FLUIDS?

Dimitry MODIN*, Gautier BAUDOT, Andre-Ramiro PEIRIN, Eric ZAGOTTO

INTRODUCTION



Basin

- Location: Atlantic Equatorial Margin
- Underexplored due to the remoteness of the area and poor previous exploration results
- Working petroleum system was proved by Shell's recent drilling campaign in the neighbor country

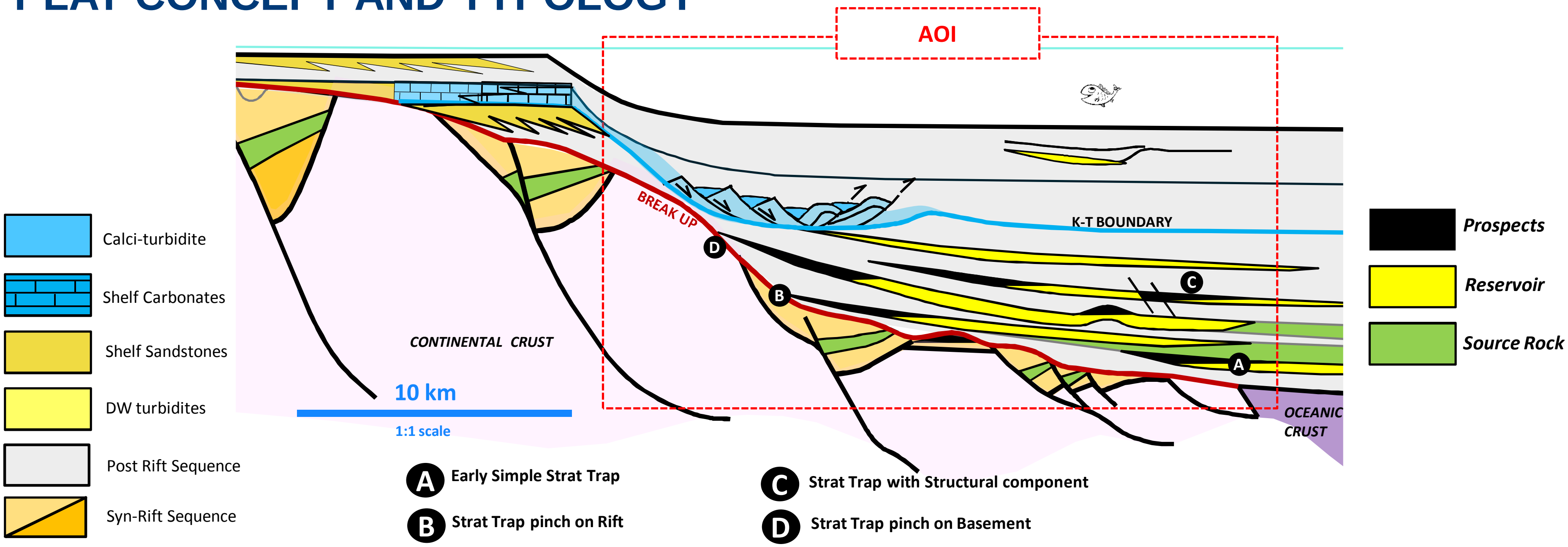
Acreage

- Several blocks (~3800 km²) acquired in 2013
- Total 40% (Operator)
- JV partners Petrobras 30%, BP 30%

Work commitment & stakes

- Technical program / commitments = several wells + 3D seismic
- Variety of plays:
  - syn-rift Albian (structural),
  - post-rift Santonian, Campanian (strati)
- 6 high graded prospects >500Mbbl each

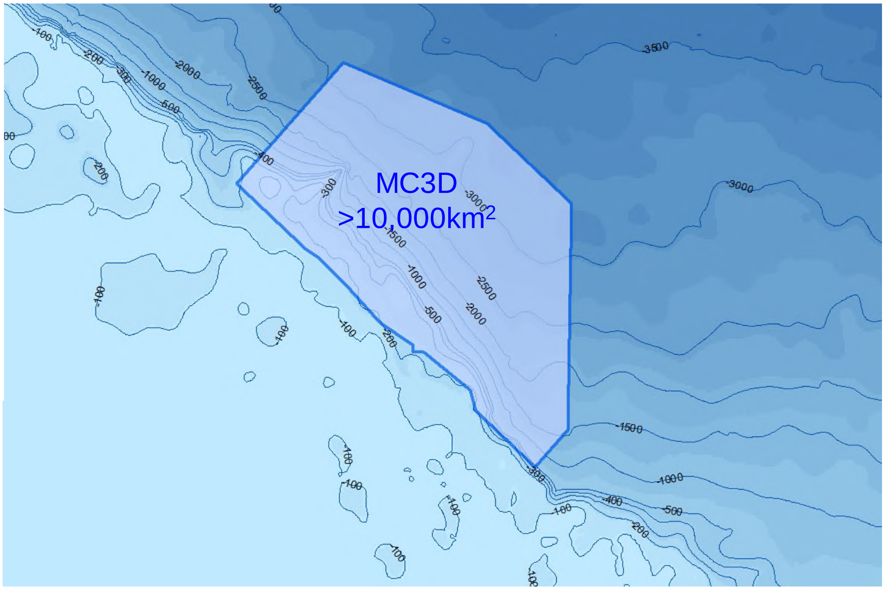
PLAY CONCEPT AND TYPOLOGY



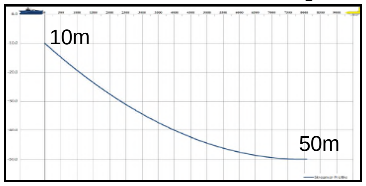
- Play variety dominated by stratigraphic trapping in the post-rift Upper Cretaceous
- Massive reservoir sands inside large multi-storey turbiditic channel complexes in the middle slope sealed by overpressured shales
- Trapping mechanism: by-pass in the upper slope, fairways are shale plugged during highstand

MULTI-CLIENT 3D LARGE SEISMIC ACQUISITION

Full Fold Area Of Interest	>10,000 km²
Acquisition direction	NE-SW (DIP)
Acquisition type	Narrow Azimuth Towed Streamers (NATS)
Acquisition Technology	**Broadband**
Number of streamers	12 streamers
Streamer depth	BroadSeis Profile

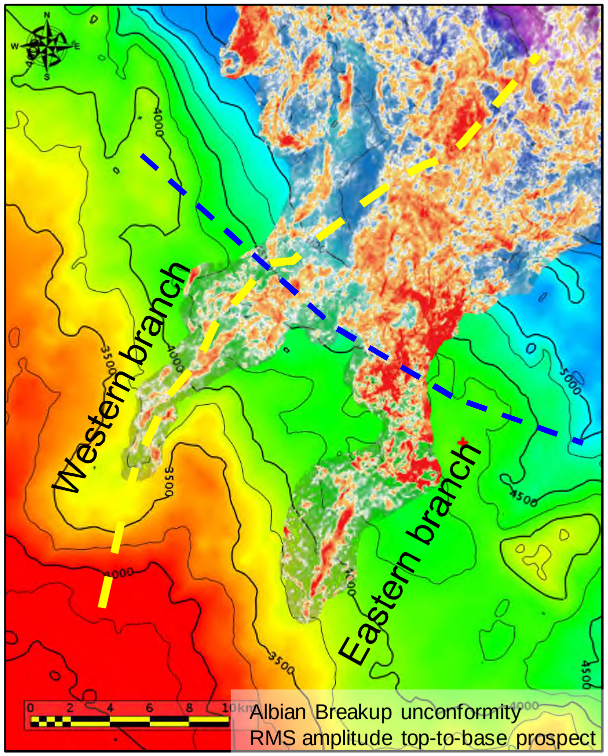


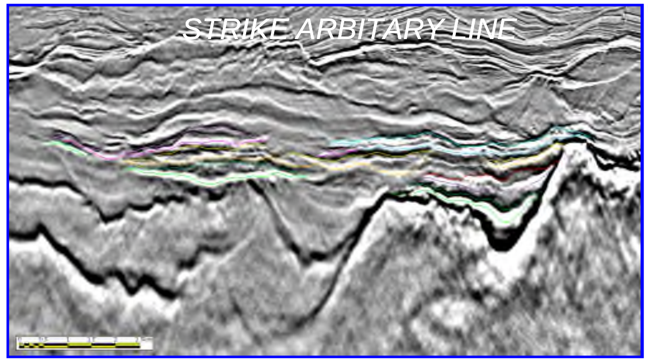
BroadSeis Profile Offset Diagram

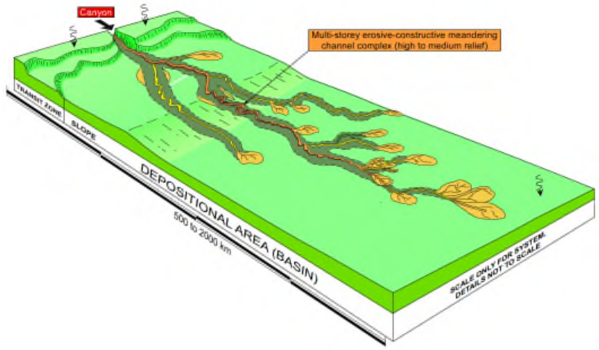


- **Acquisition completed as planned in 8 months (2014)**
- **One year processing project with the final PSDM deliverables in November 2015. <u>Main challenges:</u>**
  - seabed canyons,
  - Tertiary paleo canyons,
  - absorption by shallow anomalies,
  - VMB in slope and shallow water areas
- **Seismic products ready for:**
  - Prospect interpretation
  - Time depth conversion
  - PPP study
  - AVO study

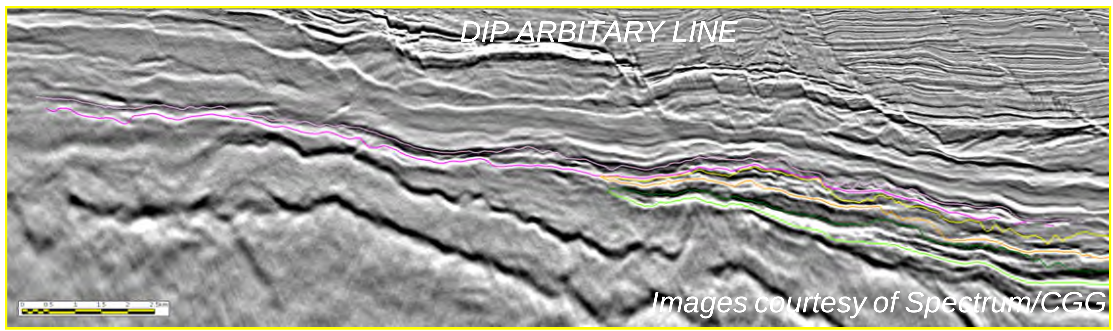
SAND FAIRWAYS MAPPING







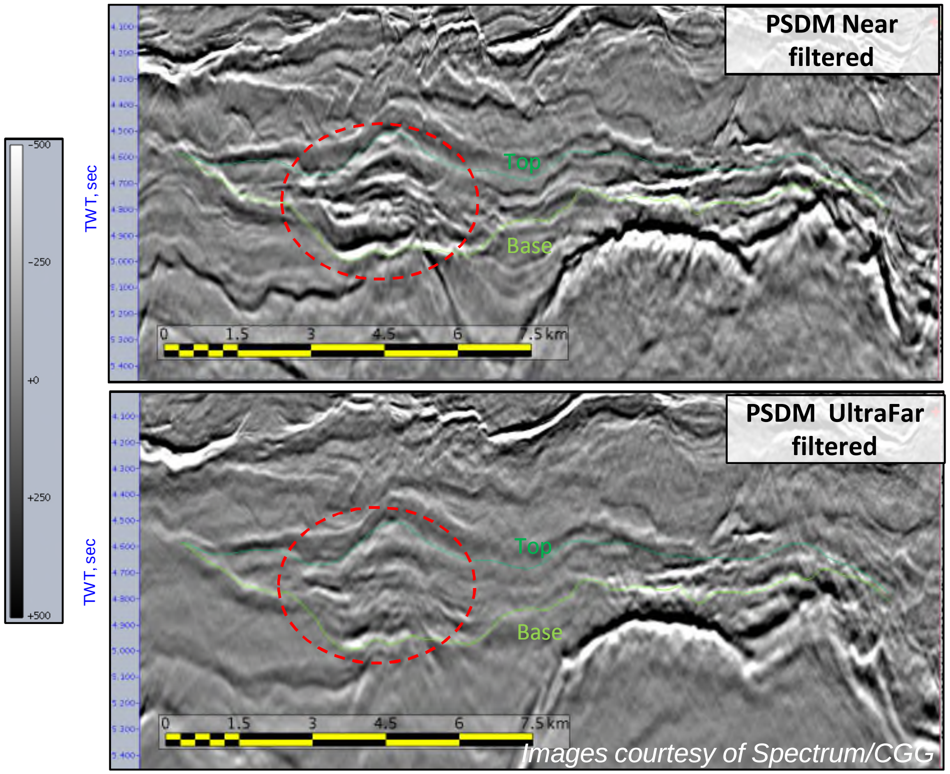
- Very large system, mature passive margin
- High density turbidites, 500-2000 km length, low slope gradient (<2°)



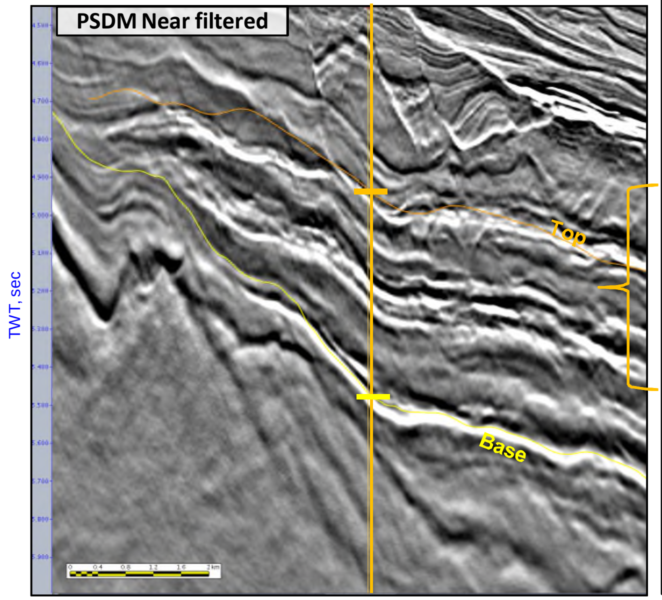
- Seismic is excelent lithology indicator - reservoir seismic facies observed all along the megacomplex
- Sealing shally facies observed on updip and downdip areas
- Compaction features observed on Western Branch
- Eastern branch deposition controlled by the basement relief

SEISMIC RESERVOIR CHARACTERIZATION & AVO

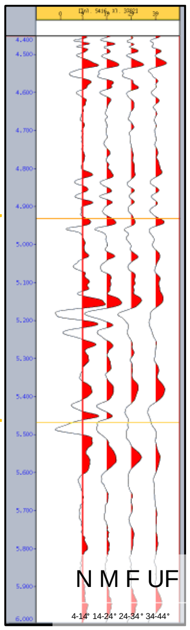
STRIKE SECTION



DIP SECTION



Pseudo gathers

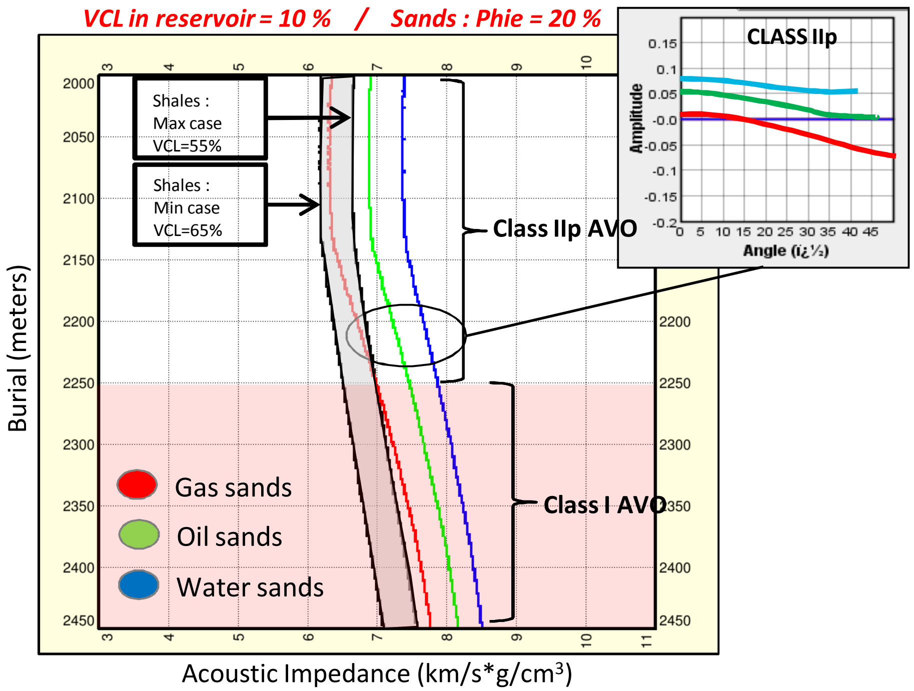


PSDM angle stacks stretched to time

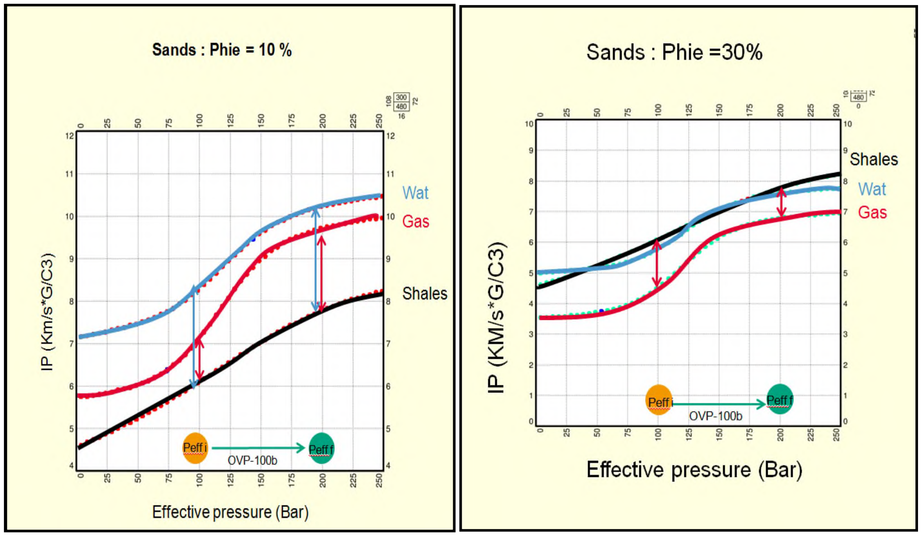
- Seismic data reveals clearly “hard” sands behavior (AVO Class I) with dimming on Fars
- No fluid effect has been observed from seismic

ROCK PHYSICS

NO FLUID EFFECT IS EXPECTED



OVP and AVO?



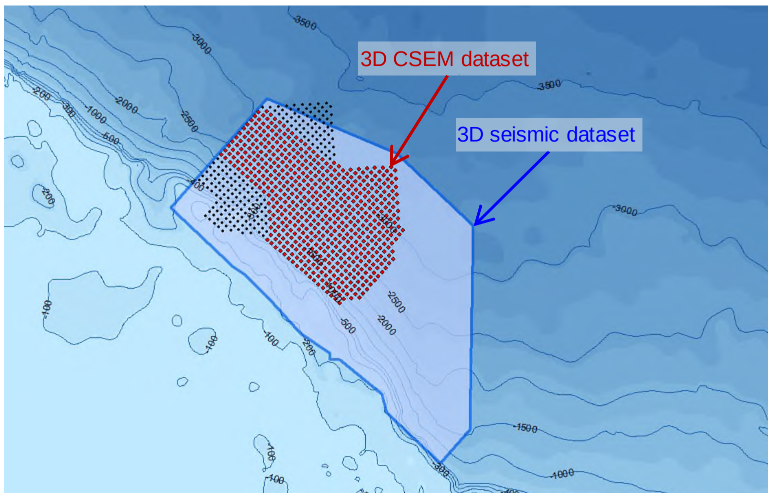
Effective Pressure = Geostatic pressure – Fluid pressure

OVP = Fluid pressure – Hydrostatic pressure

- Nearest calibration to the north → sands AVO Class I no fluid effect on seismic → AVO lithological indicator
- PEM from offset deepwater wells: clean reservoirs of VCLres=10%, PHIE=10 to 20% are AVO Class I @ prospect burial, or Class IIp for 300-500m shallower (no fluid effect could be seen on seismic)

- By increasing overpressure (↓effective pressure) in shales and reservoirs, the velocity decreases, then the fluid effect becomes stronger
- The overpressure effect doesn't affect the AVO class of sands for a given porosity

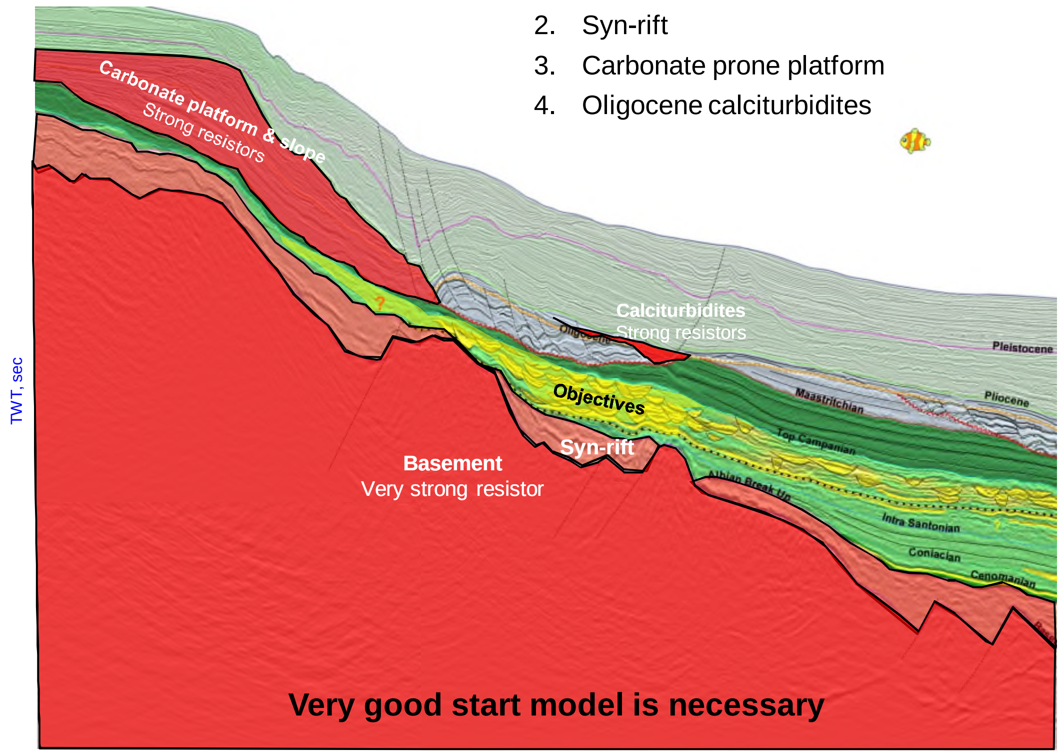
MC3D CSEM DATASET & MAIN CHALLENGES



Multi-client Acquisition & Processing

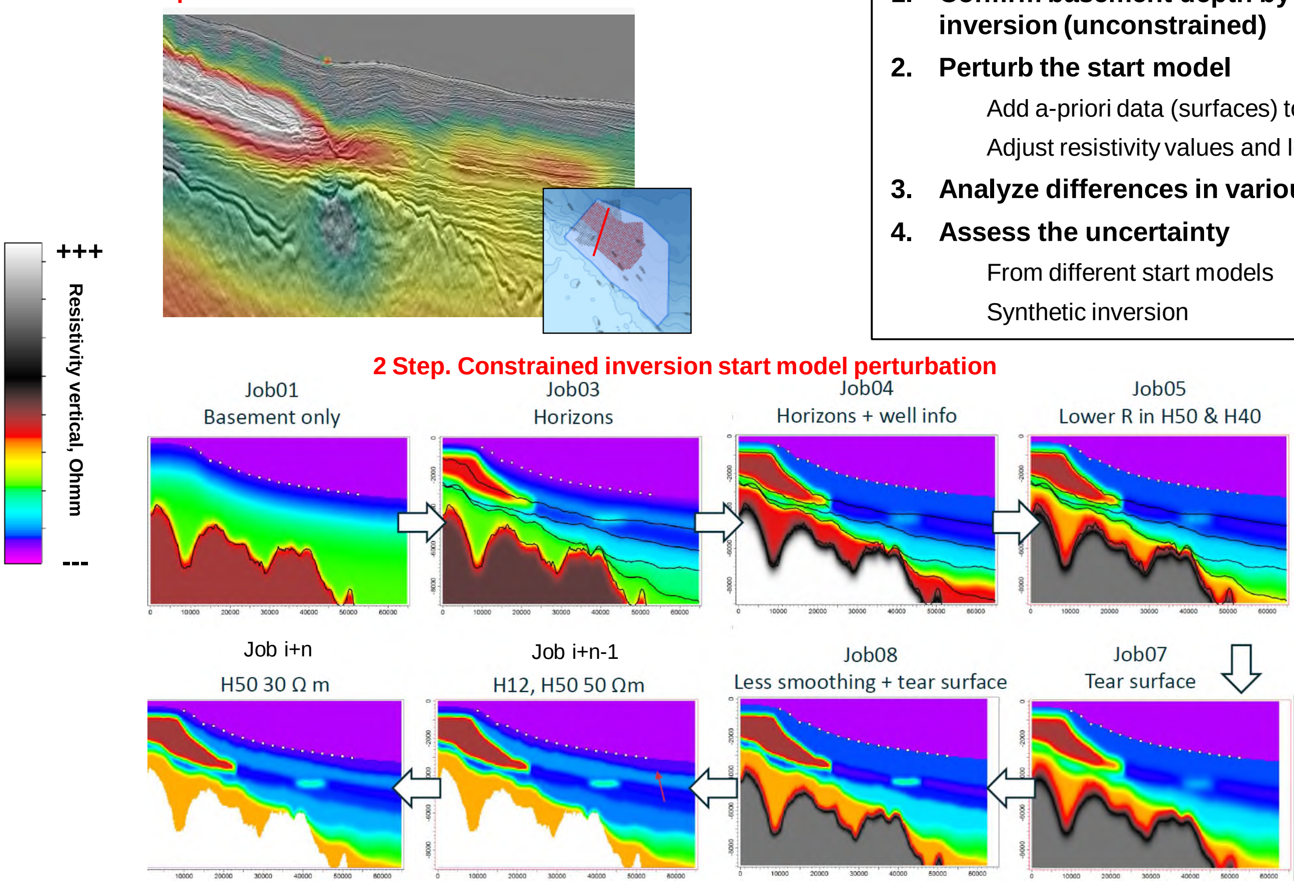
- 4500 km² acquired in 2013
- Water depth range ~200-3300m
- 791 Receivers @ 2.5 km x 2.5 km grid
- TOTAL licensed dataset: 3600 km2 (~630 receivers)

- CSEM imaging is challenging
- Strong background resistors:
  1. Basement
  2. Syn-rift
  3. Carbonate prone platform
  4. Oligocene calciturbidites



3D CSEM TOTAL PROPRIETARY INVERSION WORKFLOW

1 Step. 2.5D & 3D CSEM unconstrained inversion



1. **Confirm basement depth by CSEM purely data-driven inversion (unconstrained)**
2. **Perturb the start model**
   - Add a-priori data (surfaces) to the model
   - Adjust resistivity values and level of constraints
3. **Analyze differences in various results**
4. **Assess the uncertainty**
   - From different start models
   - Synthetic inversion

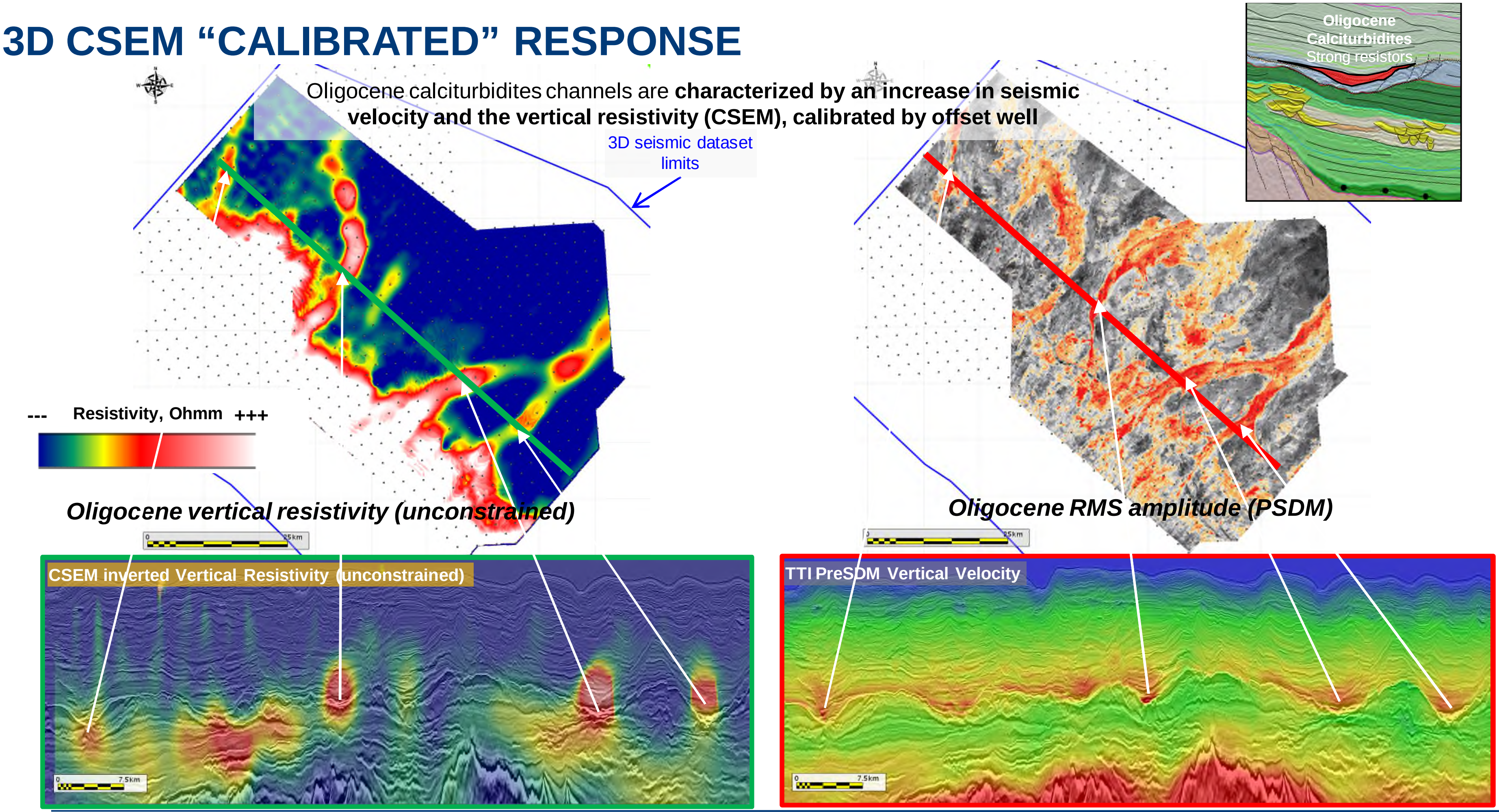
•2015 -2016 two phases of constrained inversions: more than 30 different start models tested

•Different complexity models: from "basement only" to layered including calciturbidites and carbonate platform

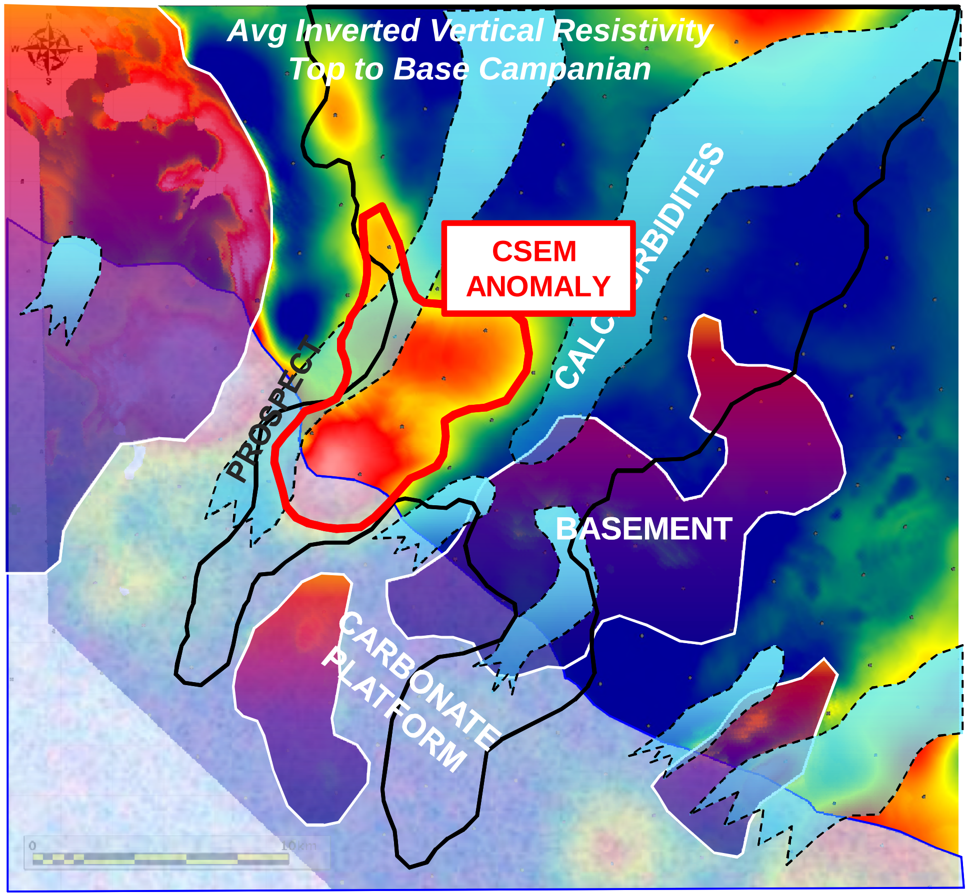
•Most robust anomalies remain in all inversion jobs

3D CSEM “CALIBRATED” RESPONSE

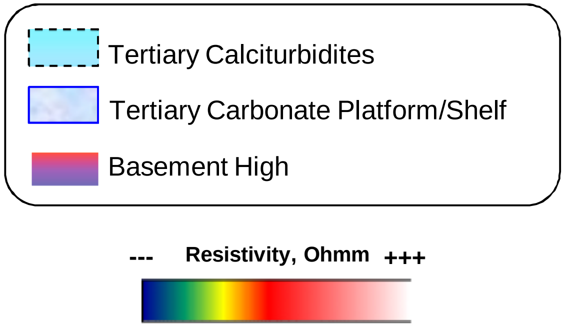
Oligocene calciturbidites channels are **characterized by an increase in seismic velocity and the vertical resistivity (CSEM), calibrated by offset well**



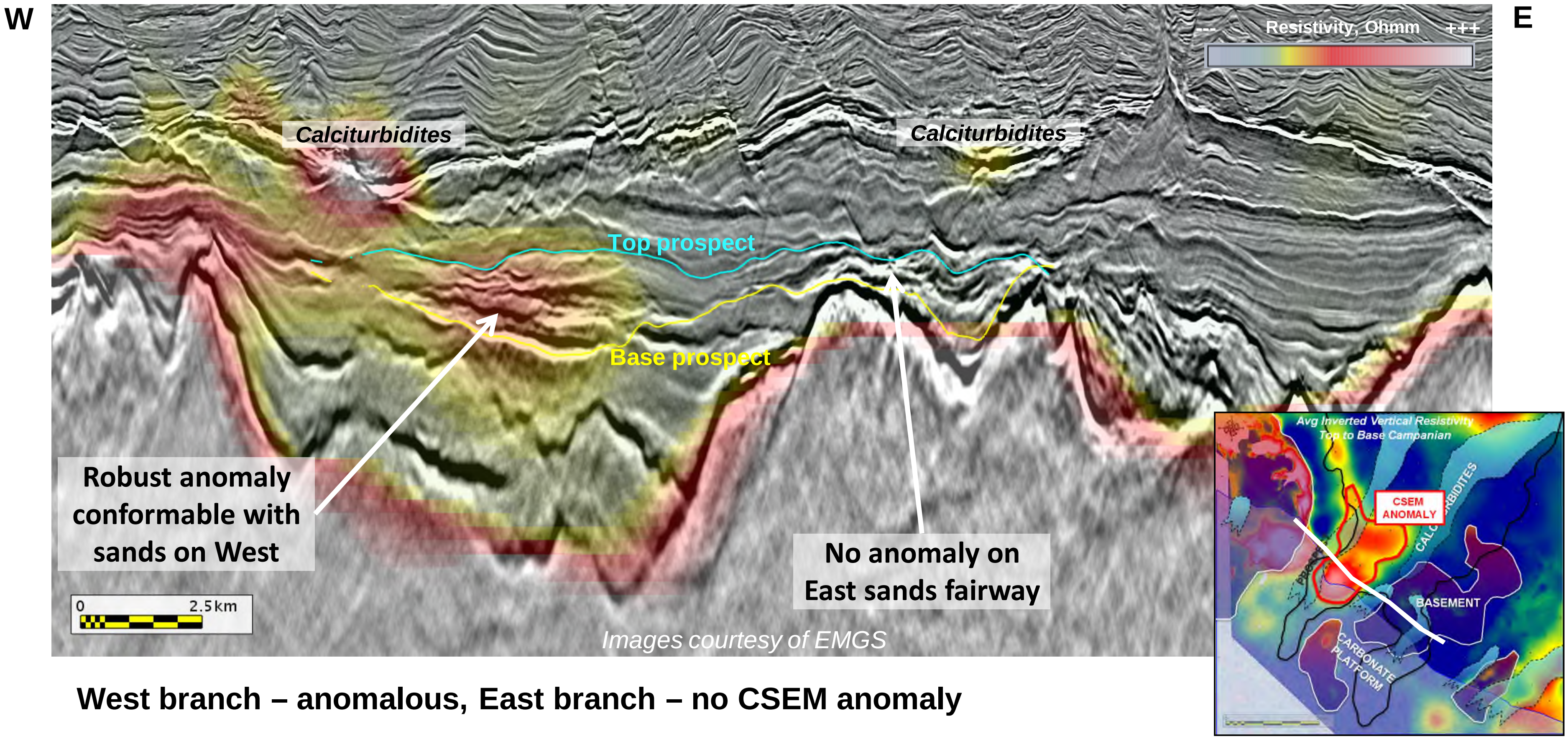
3D CSEM AVERAGE VERTICAL RESISTIVITY MAP



- •Inverted Rv resistivity map at the target interval needs to be interpreted with care
- •Effects of basement, carbonate platform, calciturbidites on the map (resistivity bleeding) need to be deconvolved
- •Robust CSEM anomaly over West branch of the prospect
- •No anomaly over East branch

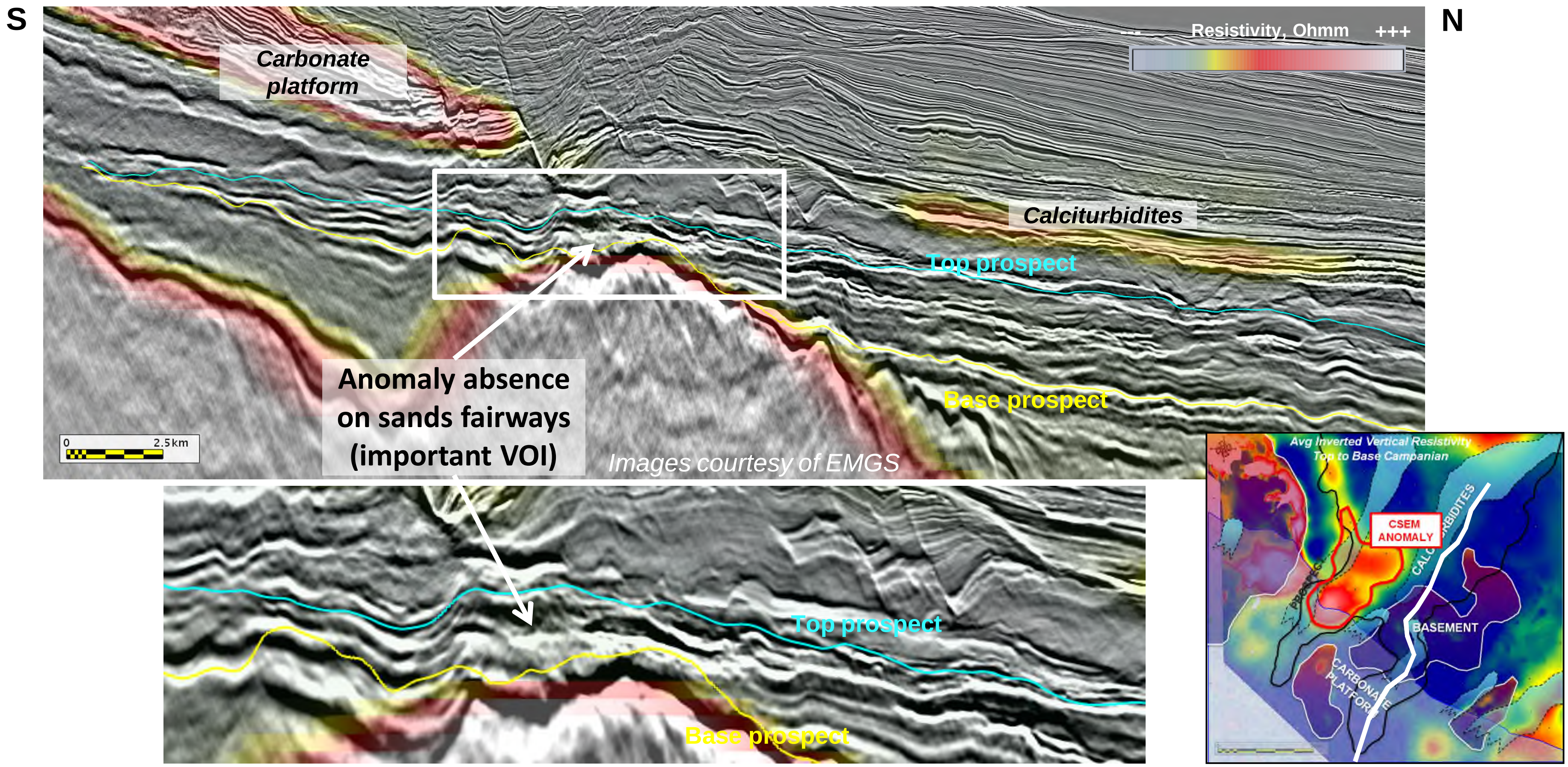


3D CSEM STRIKE SECTION THROUGH WEST & EAST BRANCHES

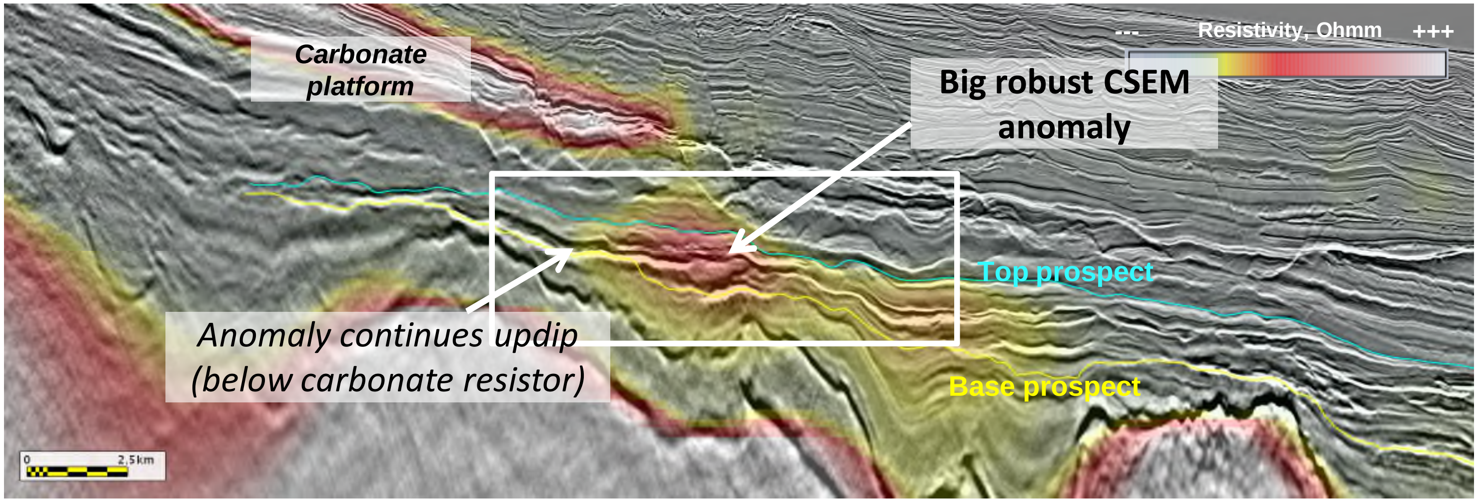


West branch – anomalous, East branch – no CSEM anomaly

3D CSEM DIP SECTION THROUGH EAST BRANCH

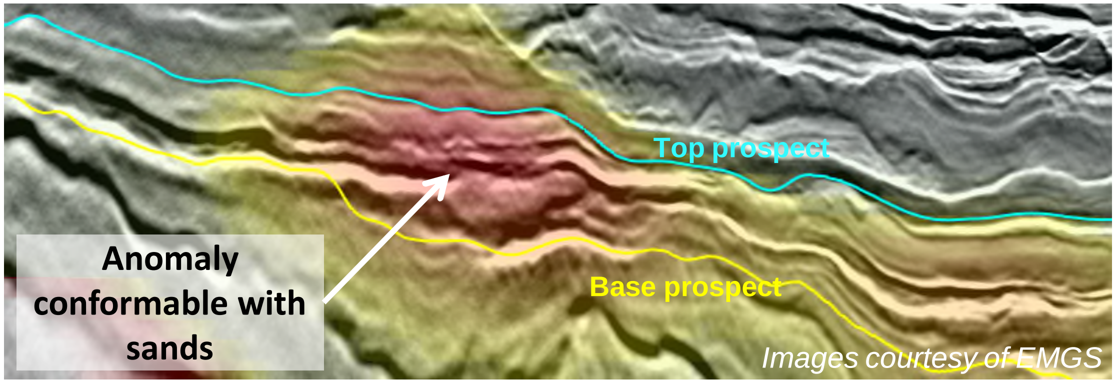


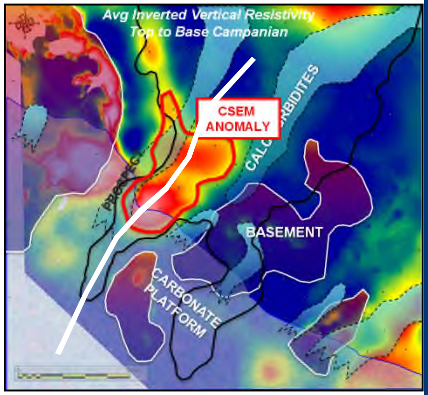
3D CSEM DIP SECTION THROUGH WEST BRANCH



Western branch

- Clearer seismic pinch-out
- Up to 4 sand intervals





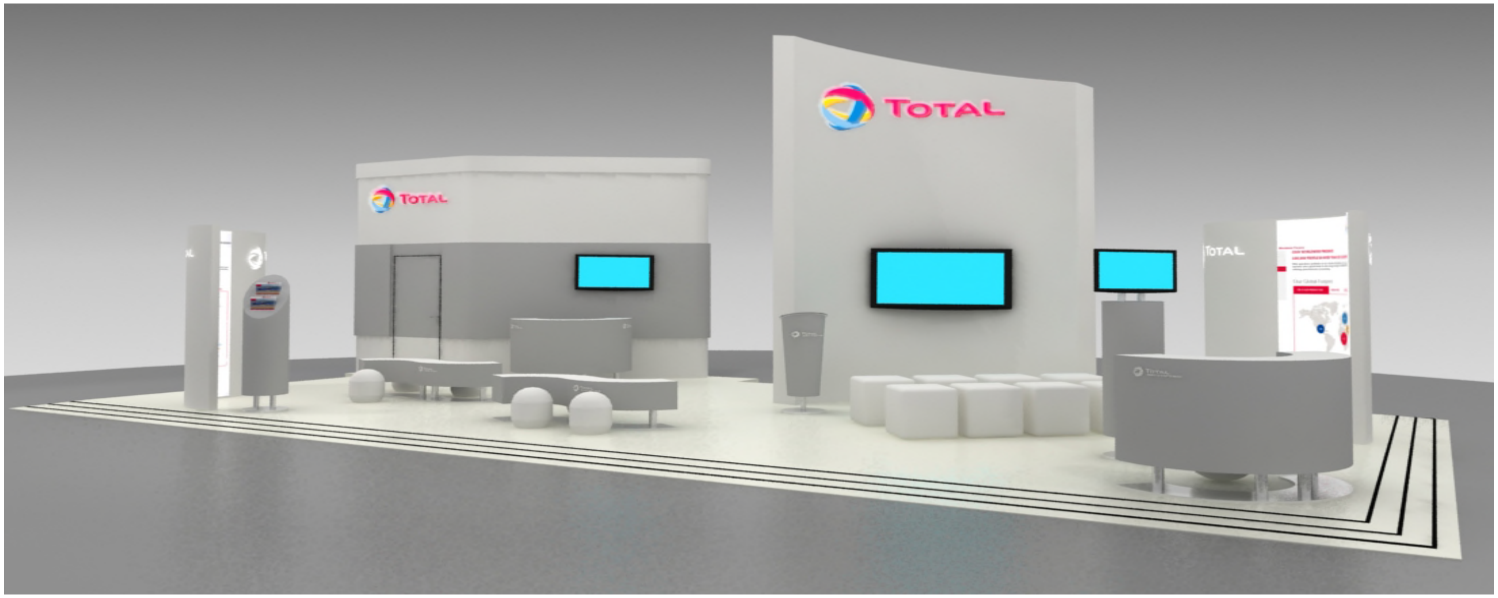
CONCLUSIONS

- **Challenging environment: deepwater and deeply buried stratigraphic traps**
- **Complex seismic imaging on the slope to define pinch-outs**
- **Not AVA/AVO DHI supported**
  - Rock-physics model from offset wells
  - Class I “hard” sands
  - No fluid effect from seismic
- **CSEM inversion response**
  - Iterative process very model and inversion algorithm dependent
  - CSEM is a resistivity measurement, and HC’s are not the only resistors - caution with nearby carbonates, volcanics, basement
  - Complex background model but implicitly “calibrated” on offset deepwater wells
  - Robust resistive anomalies are identified in the Campanian prospect interval
- **Integration with seismic is a key**
  - Eastern branch of the prospect: no CSEM anomaly observed even in “non contaminated by surrounding resistors” window - important VOI
  - Western branch of the prospect: CSEM anomaly present – consistent in all iterations, it is conformable with the Upper sands fairway geometry (800 Mbbl), better seismic pinch-out quality → to be drilled this year

THANKS FOR AUTHORIZING SHOWING THE DATA

JUST DROP BY THE TOTAL STAND

HALL E – 2033



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