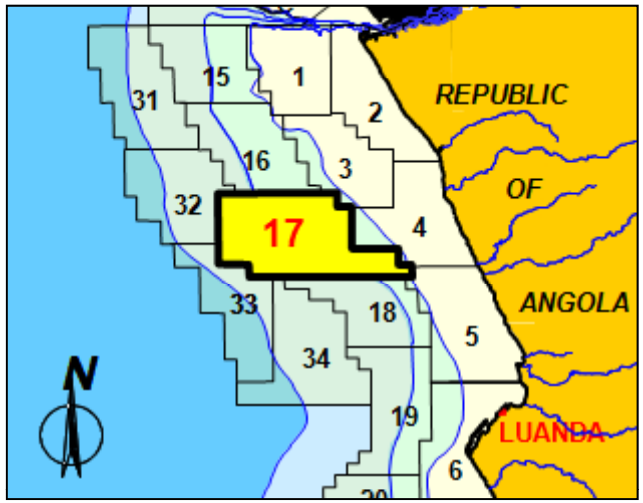
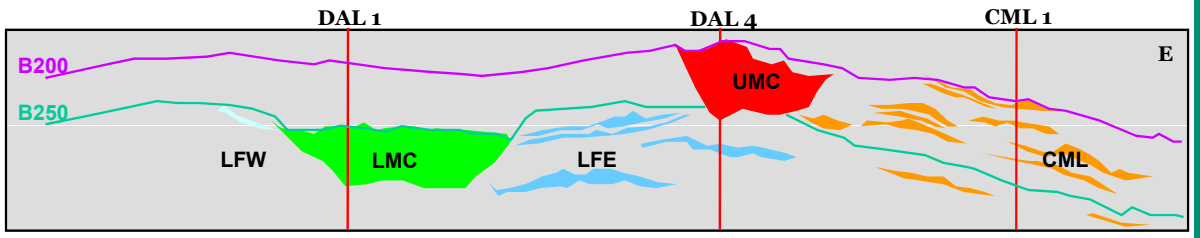
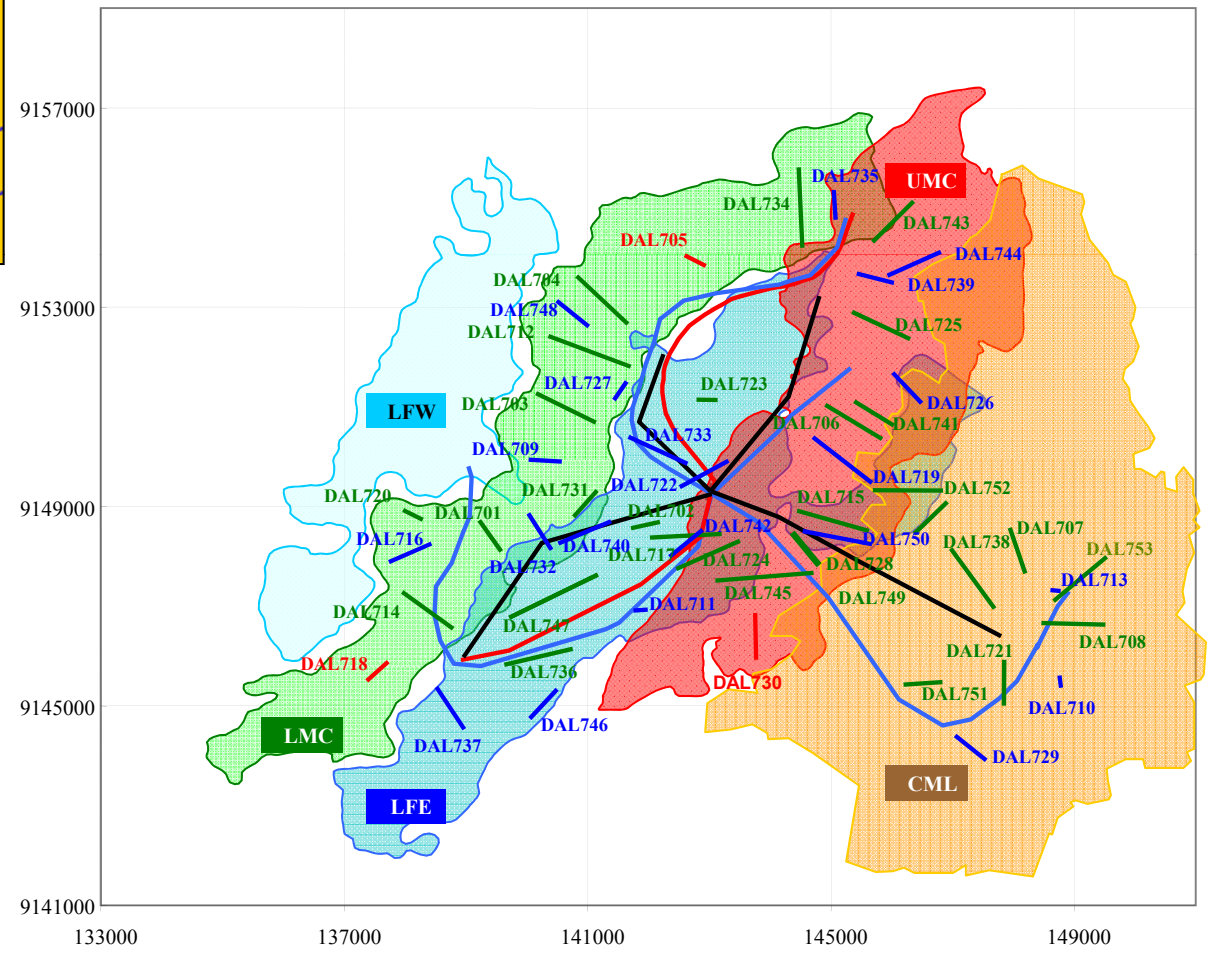
INNOVATIVE EOR & 4D SEISMIC ACHIEVEMENT IN DEEP OFFSHORE

Renaud GAUCHET, Total E&P Russie

DALIA FIELD







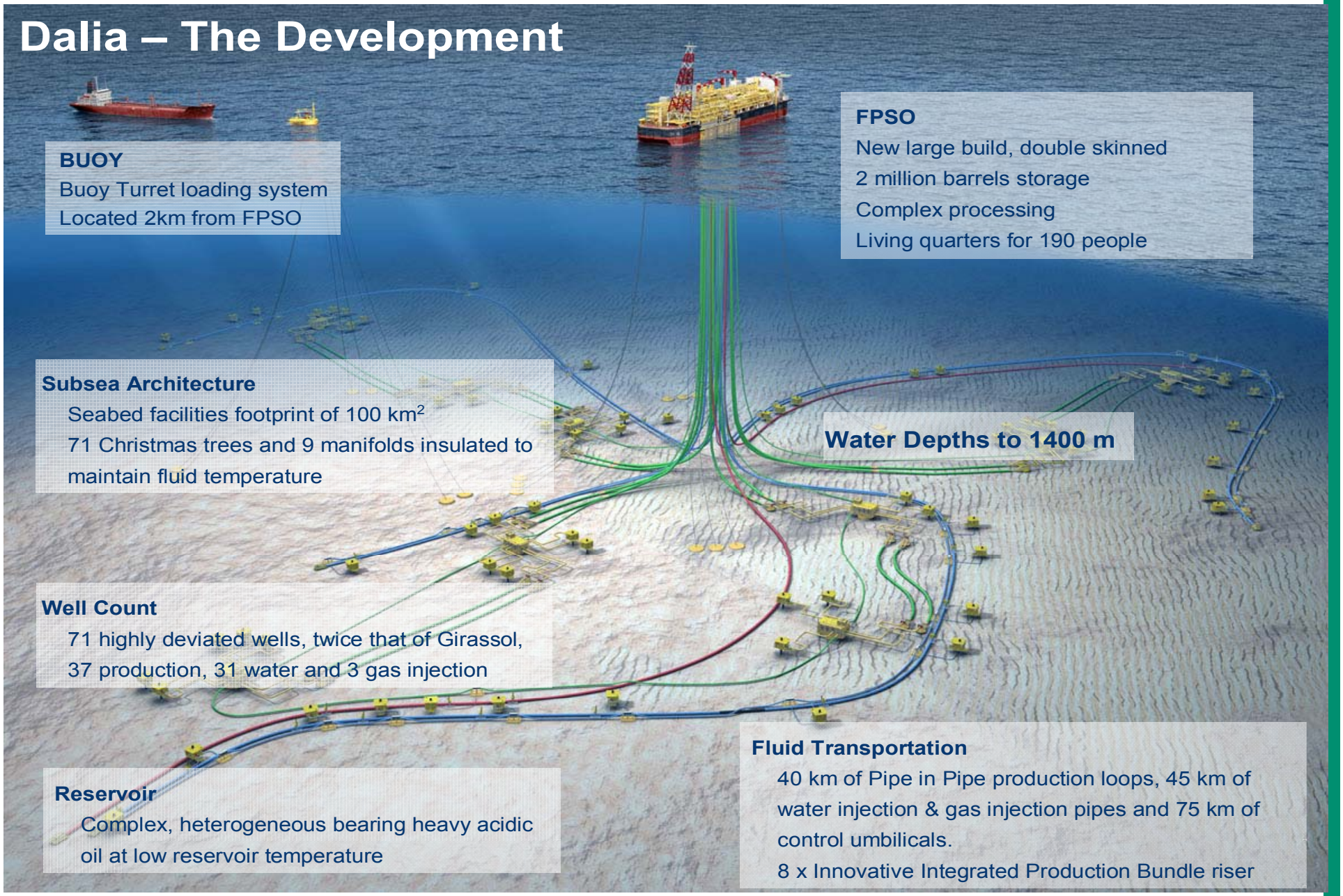
Block 17 Partnership:

TOTAL (op)	40.00 %
ESSO	20.00 %
BP	16.67 %
STATOIL	23.33 %

First Oil:

Girassol	Dec. 2001
Jasmim	Nov. 2003
Dalia	Dec. 2006
Rosa	Apr. 2007
Pazflor	Aug. 2011
CLOV	June 2014

Dalia – The Development



BUOY
Buoy Turret loading system
Located 2km from FPSO

FPSO
New large build, double skinned
2 million barrels storage
Complex processing
Living quarters for 190 people

Subsea Architecture
Seabed facilities footprint of 100 km^2
71 Christmas trees and 9 manifolds insulated to maintain fluid temperature

Water Depths to 1400 m

Well Count
71 highly deviated wells, twice that of Girassol,
37 production, 31 water and 3 gas injection

Reservoir
Complex, heterogeneous bearing heavy acidic oil at low reservoir temperature

Fluid Transportation
40 km of Pipe in Pipe production loops, 45 km of water injection & gas injection pipes and 75 km of control umbilicals.
8 x Innovative Integrated Production Bundle riser

POLYMER INJECTION ON DALIA

Objective : Enhance sweep efficiency thanks to

- mobility ratio reduction between water & oil (viscosity)
- Permeability reduction to water (adsorption - RRF)

Mature Technique

- More than 170 projects worldwide

Adapted for reservoirs :

- With high permeability (few Darcy)
- At low temperature (30-70 °C)
- With high oil saturation
- Viscous oil (few cP +)

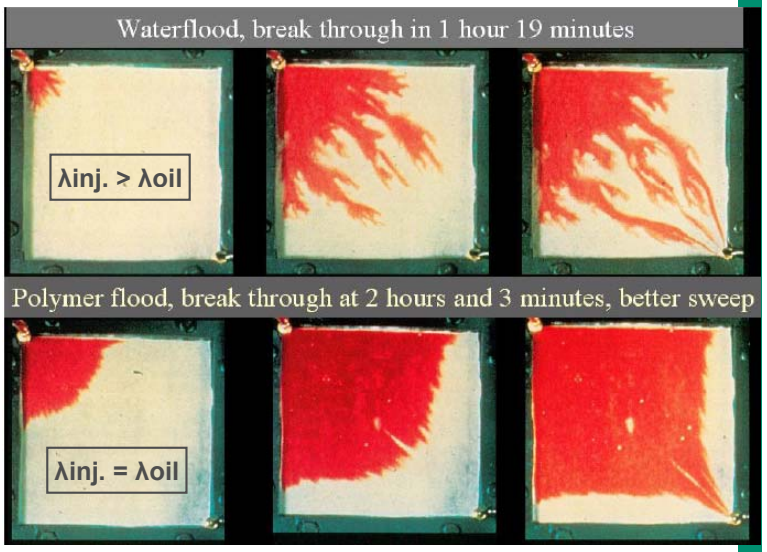
Dalia is a good candidate but :

- 1st offshore operation
- High salinity
- Large spacing : high injection rate per well

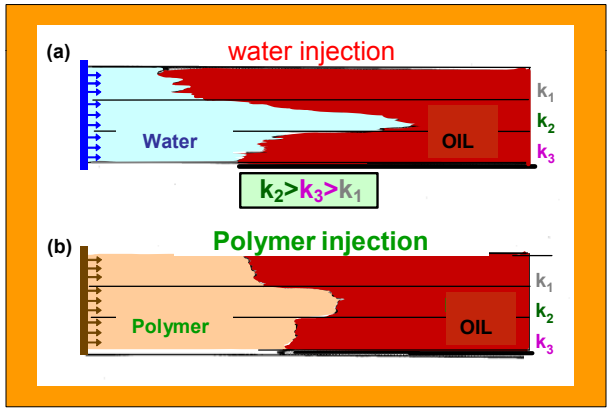
Polymer selection criteria

- High molecular weight Polyacrylamide
- Sensitivity to shear (ex: choke, pump valves ..)
- Sensitivity to salt
- Supplier: very few suppliers worldwide
  (SNF at St Etienne is the worldwide leader, Fab. USA & Europe)

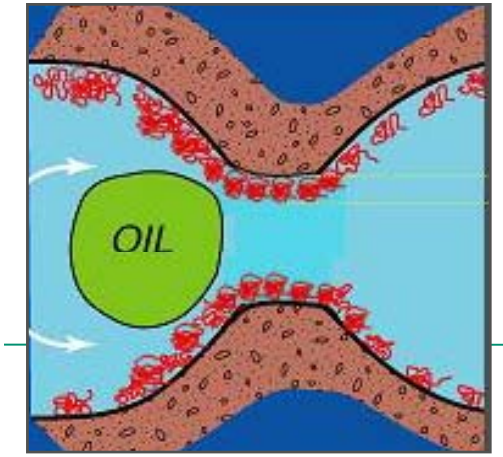
AREAL SWEEP EFFICIENCY



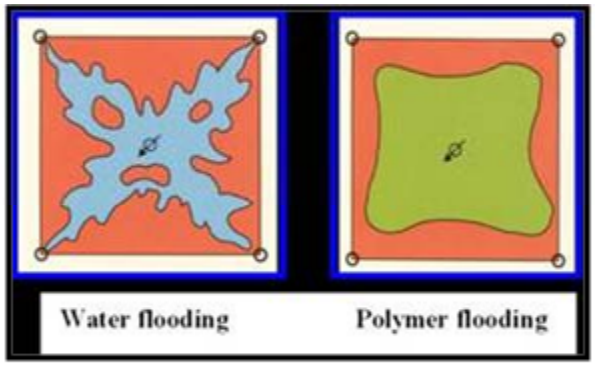
VERTICAL SWEEP EFFICIENCY



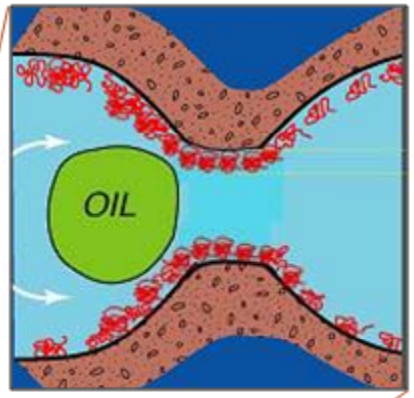
Polymer adsorption : Resistance to the flow (RRF)

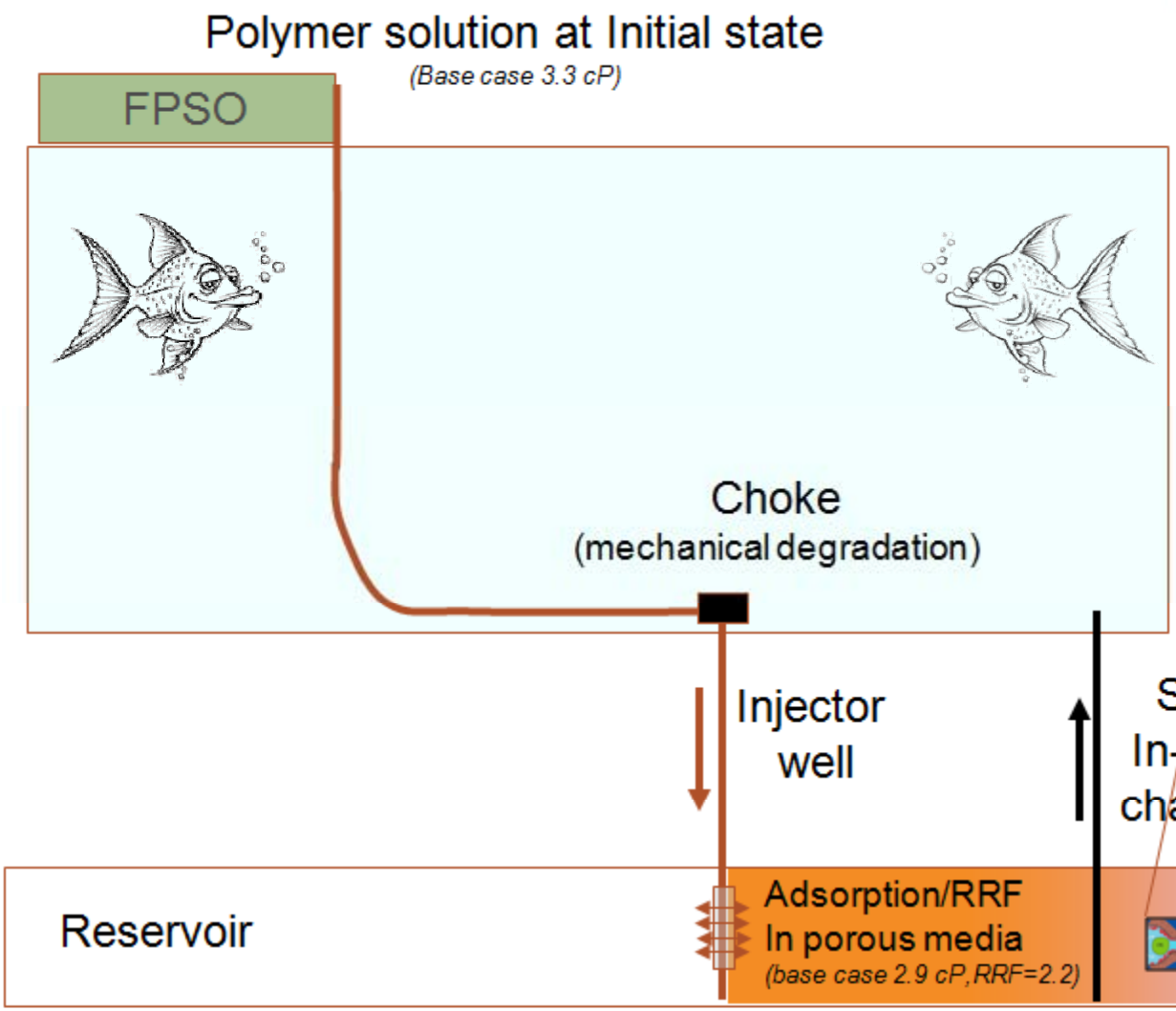


DALIA VISCO. MECHANISMS



Residual Resistance Factor effect on Krw at Sorw

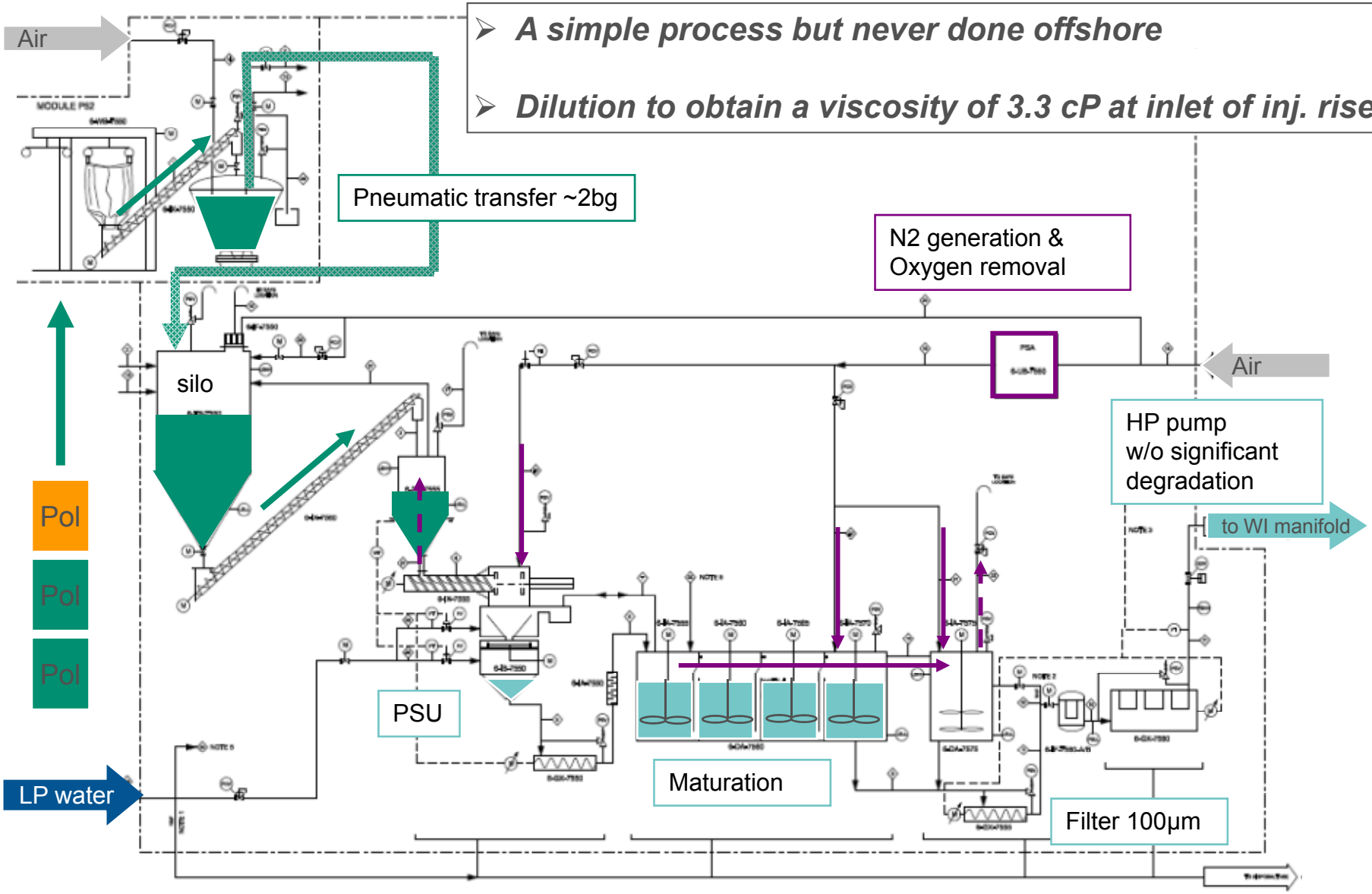




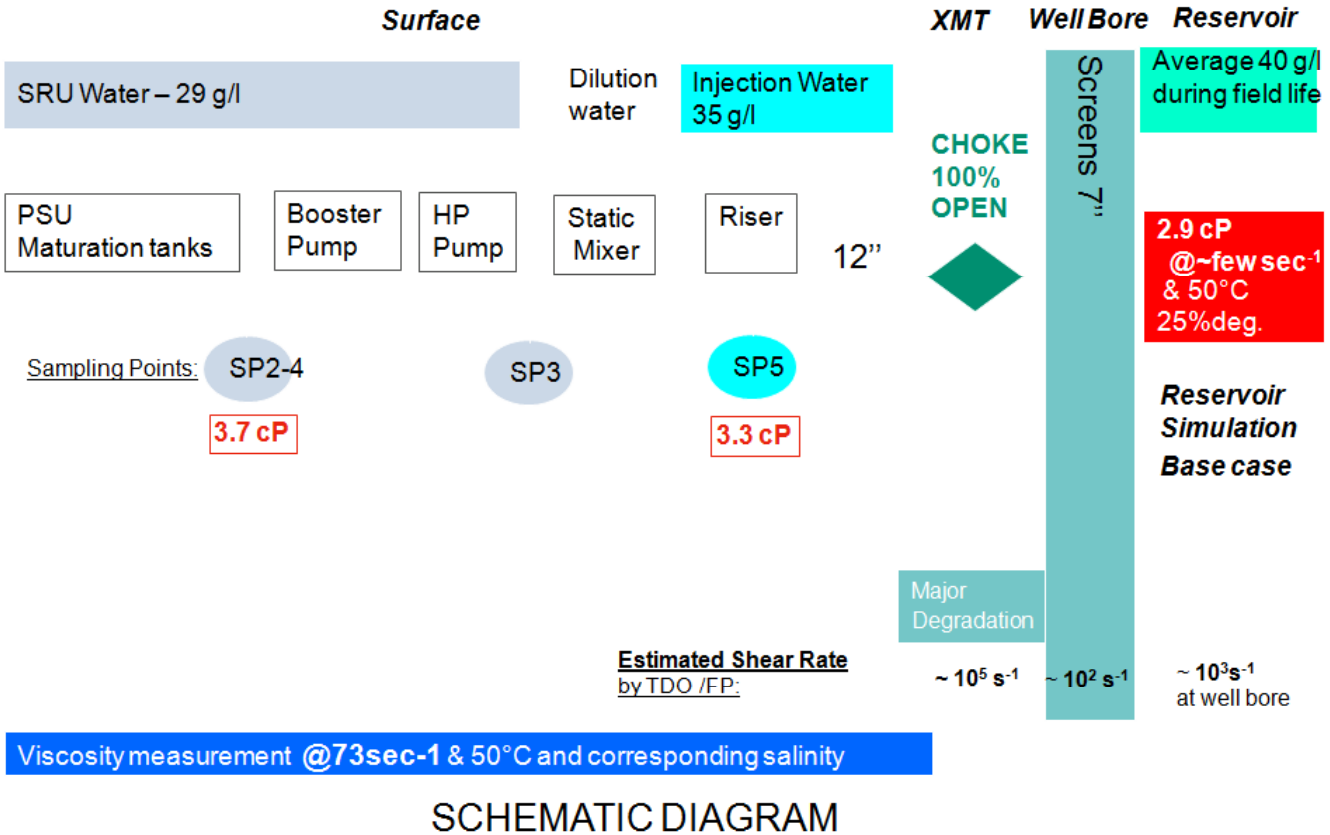
Schematic Diagram

FABRICATION OF THE POLYMER SOLUTION

- ***A simple process but never done offshore***
- ***Dilution to obtain a viscosity of 3.3 cP at inlet of inj. riser***



SKID & OFFSHORE TEST CONDITIONS

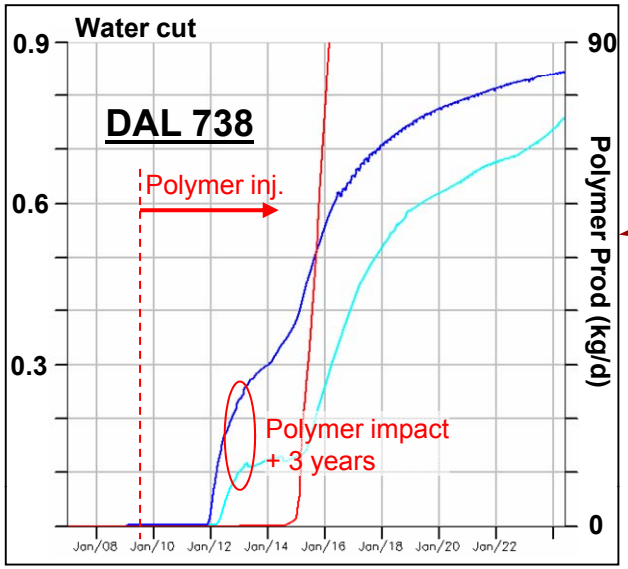


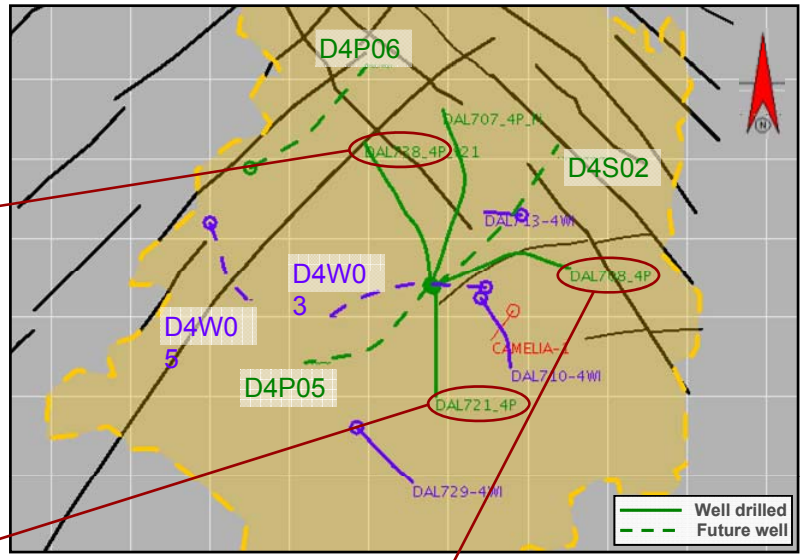
SCHEMATIC DIAGRAM

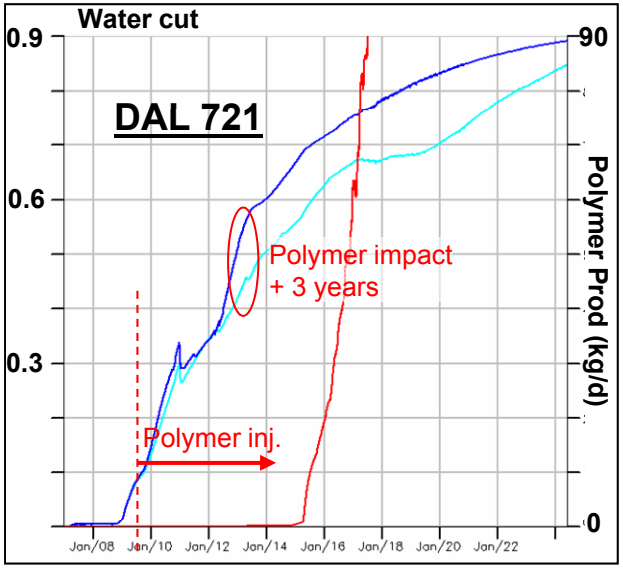
Polymer Injection Skid on Dalia FPSO

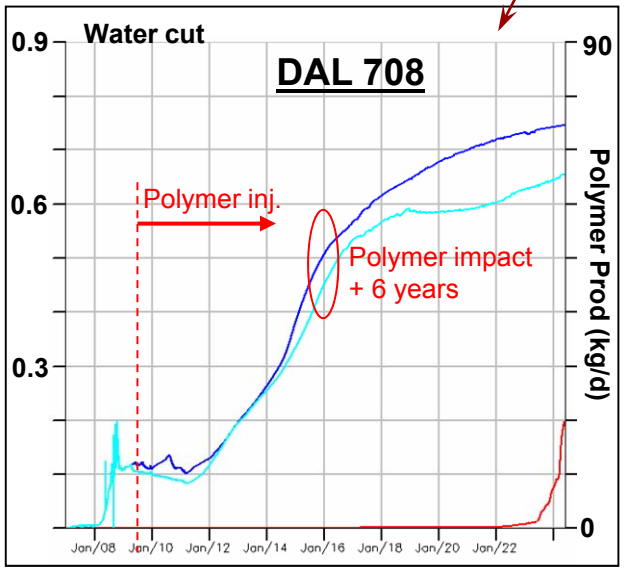
TOTAL

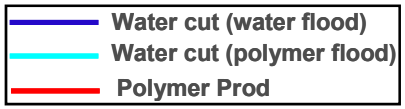
POLYMER INJECTION – IMPACT ON PROD. PROFILE











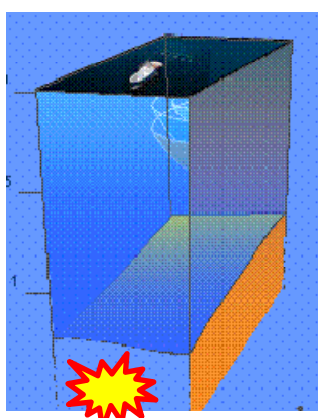
Decision of a phased approach for this World 1st drilling of a sampler well ⇨ early evaluation of in situ viscosity

TOTAL

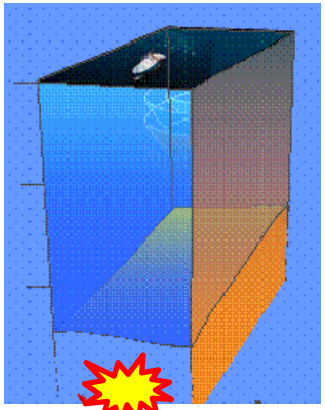
DALIA 4D SEISMIC MONITORING PROGRAM

❖ **Baseline 3D HR seismic (1999): Streamer Single vessel acquisition**

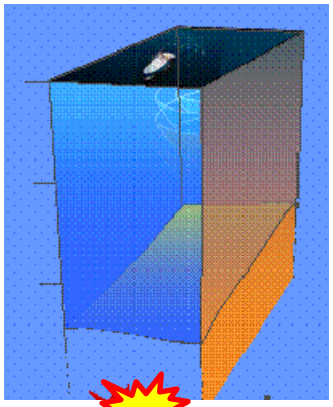
- **Intensively used:** Structural modeling, sedimentological Architectural Elements extensions, Facies modelling, Wells Geosteering



1999



2008



2010

Time

Dec. 2006 — First Oil

1.5 year — Water & Gas injection

2009 — Polymer injection

3.5 year

Before Production

4D MONITORING OBJECTIVES

Field delineation & FDP definition - 4D Baseline

Gas & Water monitoring - Depletion monitoring Reservoir model matching

Use of these two monitors to design the well sampler

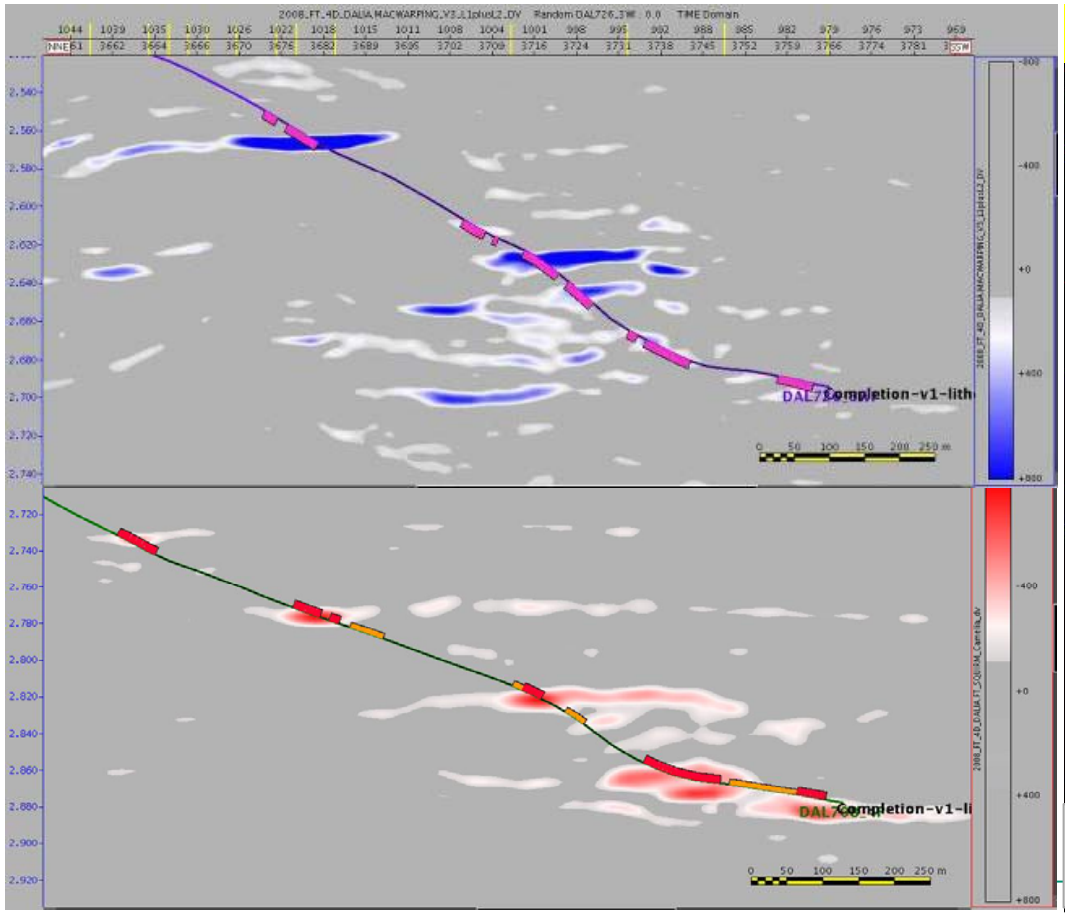
4D SEISMIC : TOTAL WORKFLOW

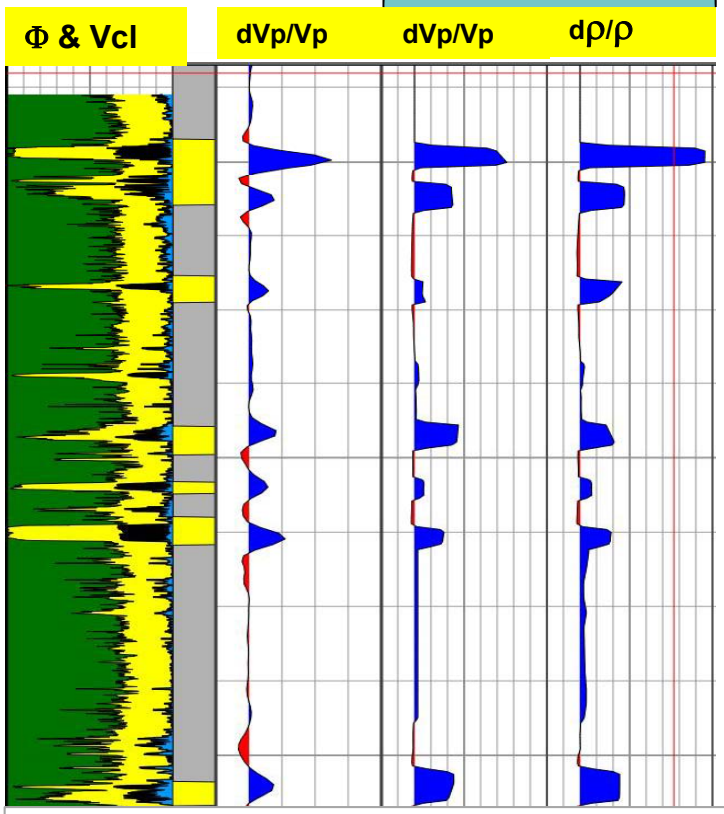
❖**4D seismic attributes based on In House inversion software**

- **➔ wide spectrum volumic attribute : dVp/Vp**

> 0 ⇔ water injection (in blue)

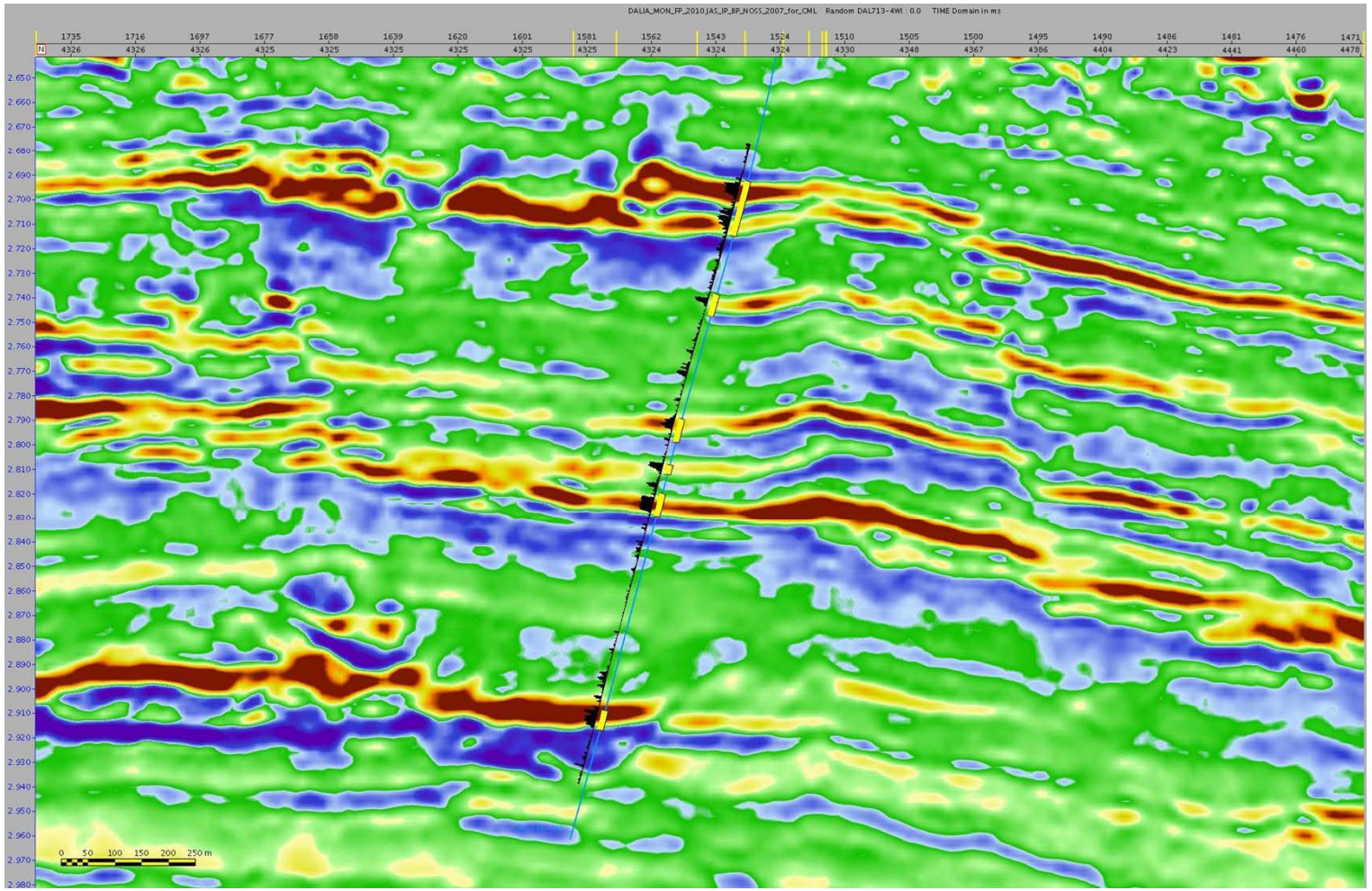
< 0 ⇔ Gas exsolution (in red)



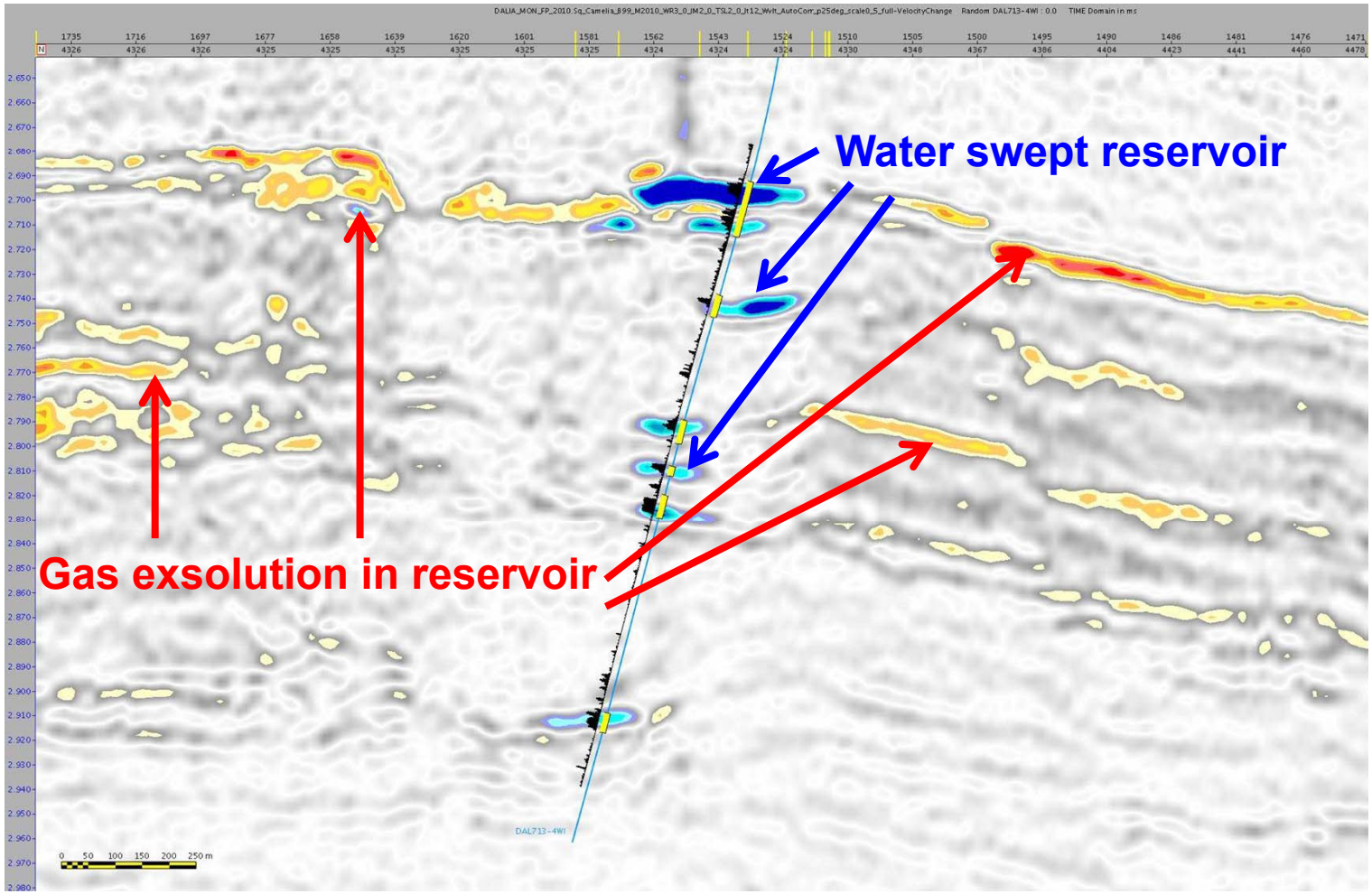


Rock Physics Model: (Vp, Vs, ρ) = f(petrophy)
➔ to anticipate 4D signature

PSEUDO IMPEDANCE : SAND/SHALE



DVP/VP : BLUE = WATER; RED = GAS IN OIL

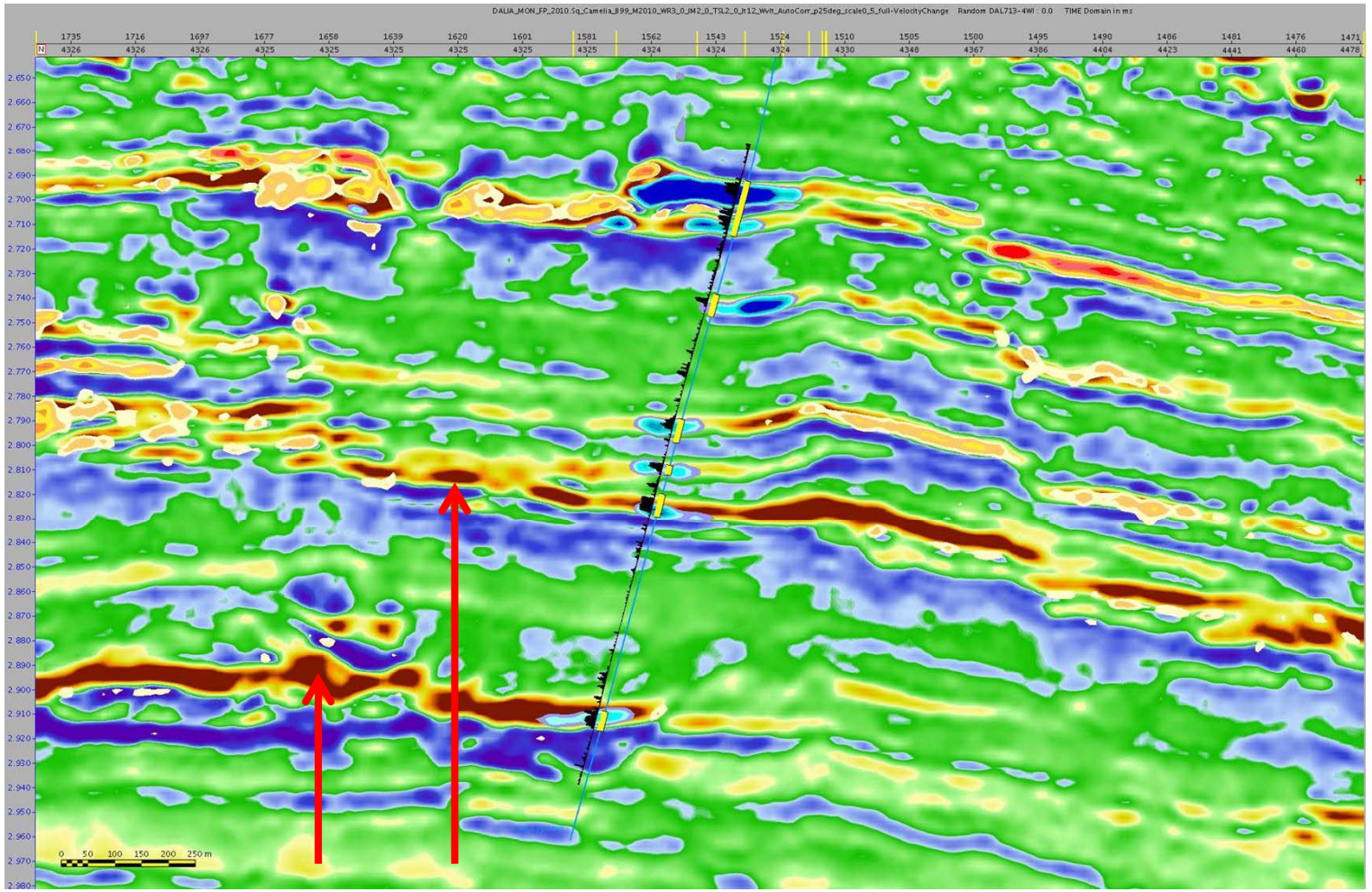


Cx13

To

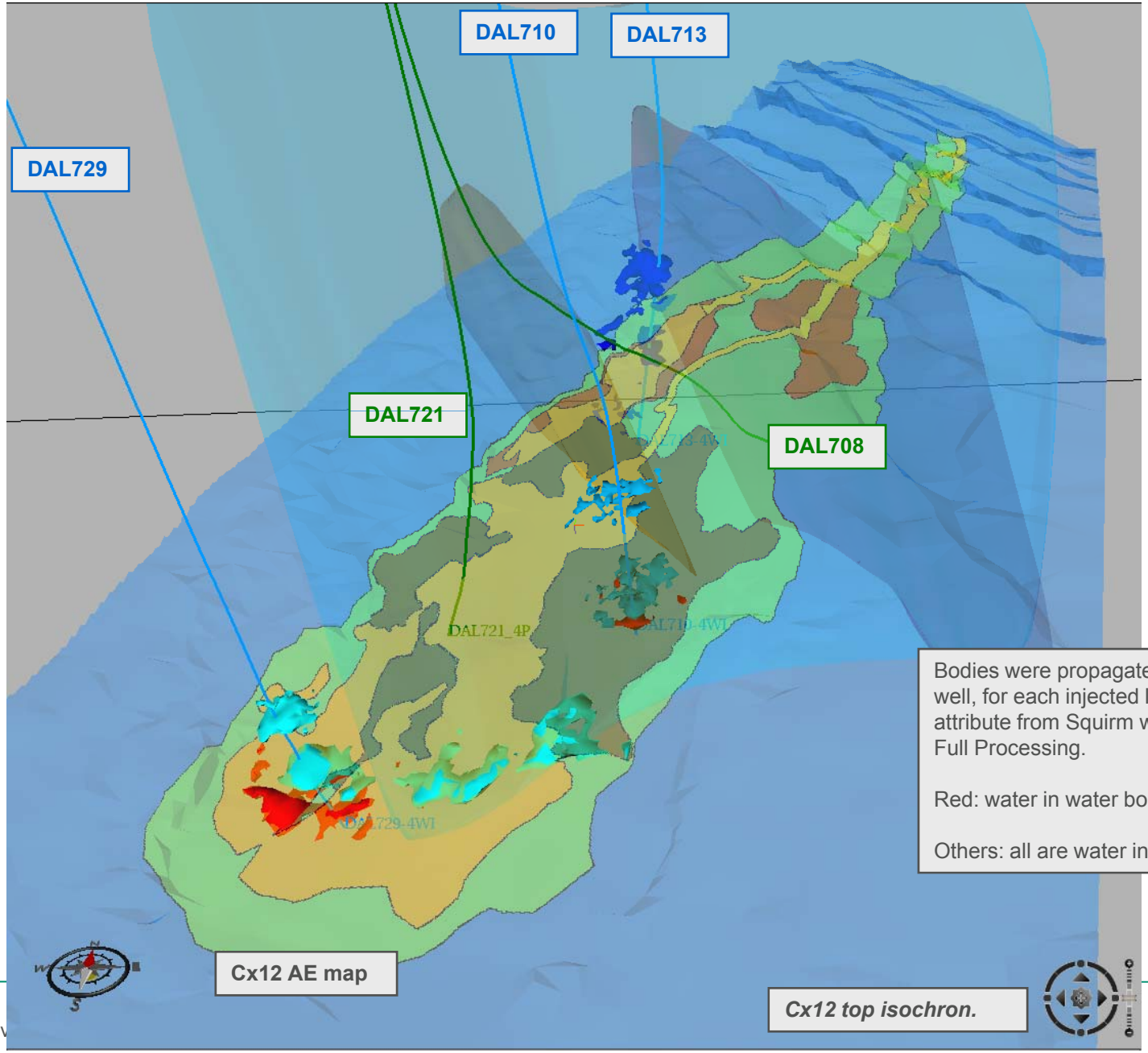
Cx3

DVP/VP ON PSEUDO IMPEDENCE



Non produced reservoirs Cx3 & Cx8

3D VIEW OF PICKED BODIES ON DV/V

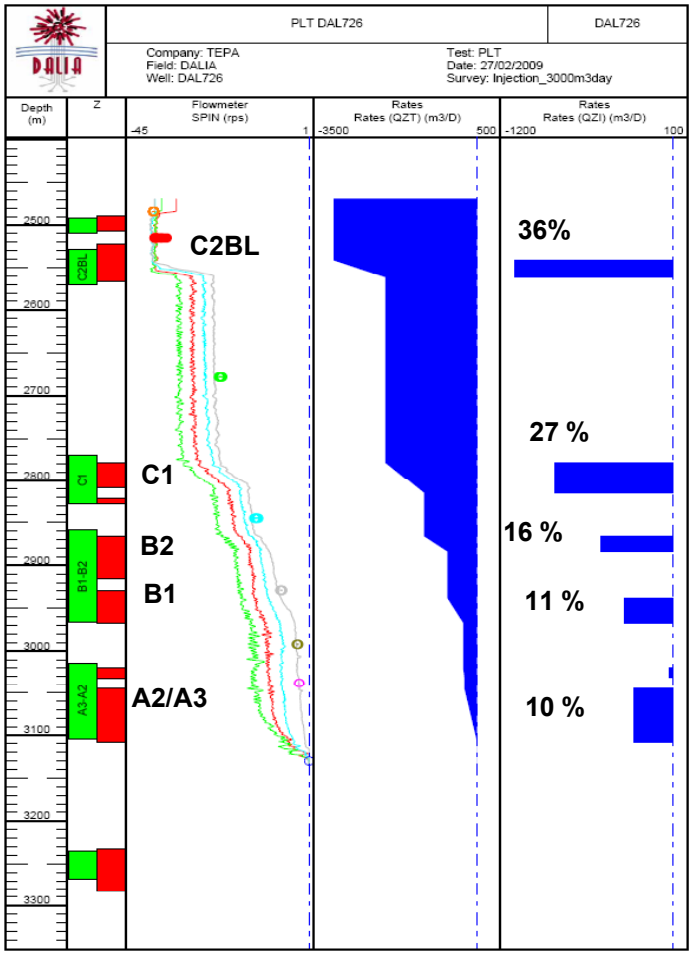


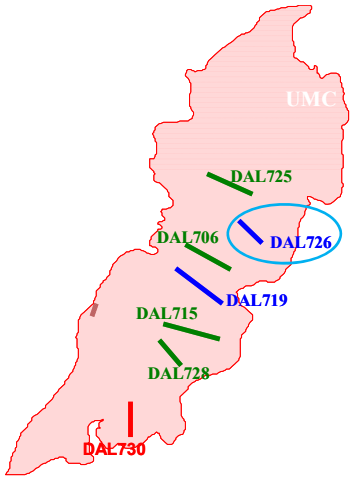
Bodies were propagated for each well, for each injected level, on dv/v attribute from Squirm warping on Full Processing.

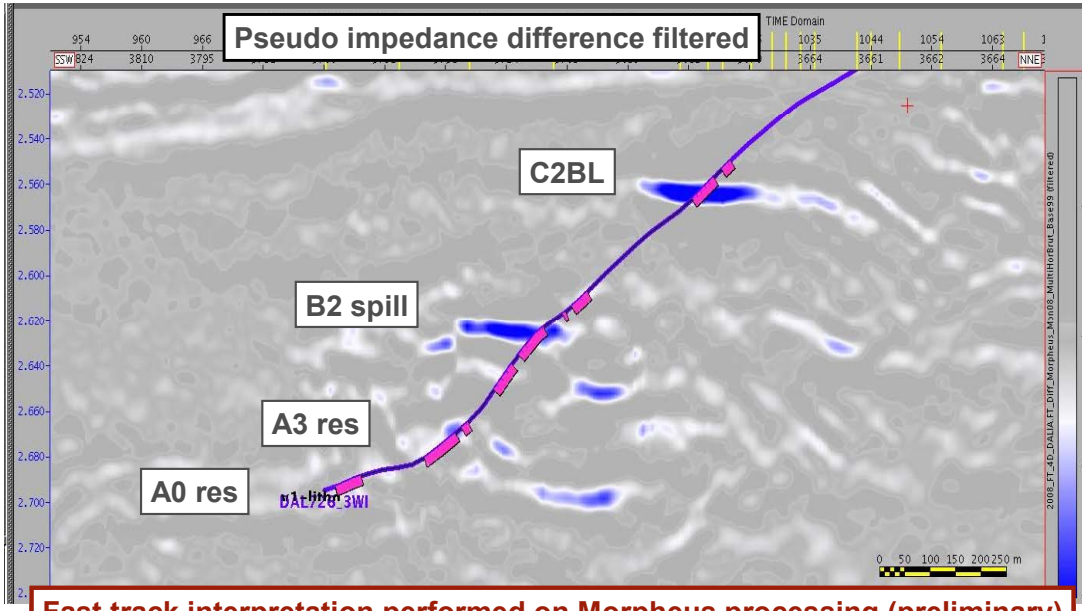
Red: water in water bodies.

Others: all are water in oil bodies.

DAL726 – PLT VS. 4D







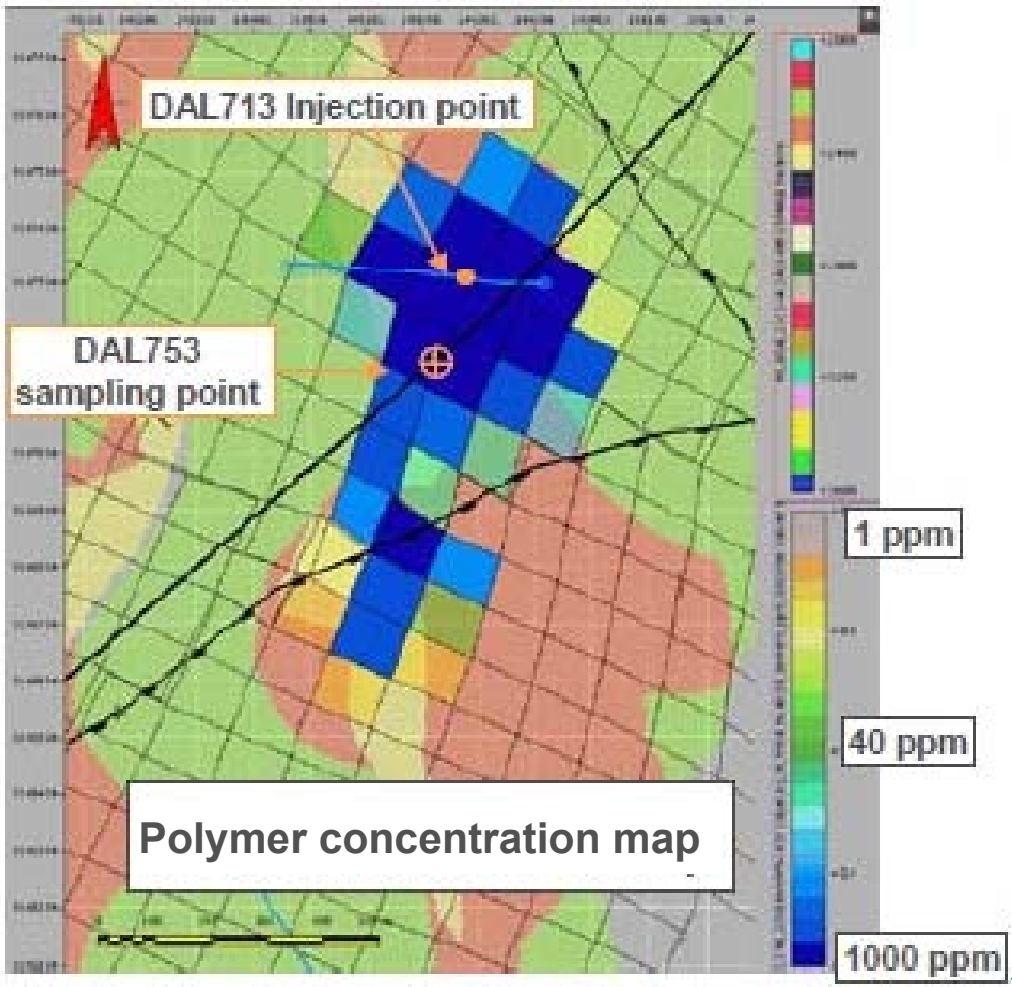
Fast track interpretation performed on Morpheus processing (preliminary)

Fairly good agreement between PLT and 4D effects

FIT OF RESERVOIR MODEL AND 4D RESULTS

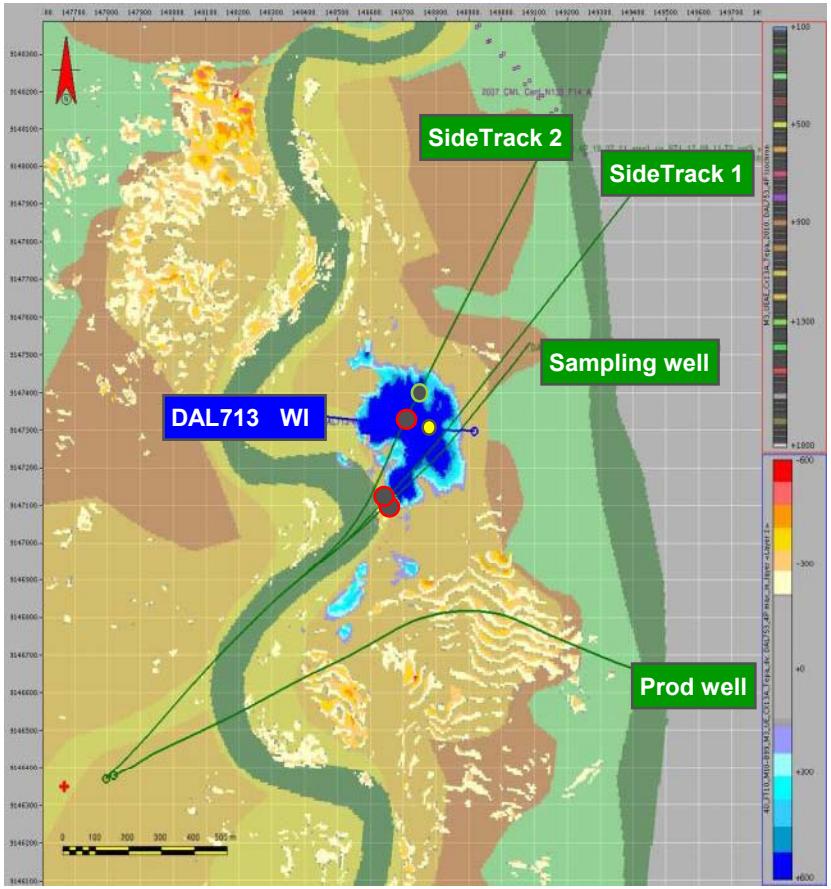
4D FT 2010 dVp/Vp over Cx13A AE

Reservoir model



SAMPLING WELL RESULTS

4D FT 2010 dVp/Vp over Cx13A AE



- Entry point in Cx13A reservoir
- Base Cx13A @ SideTrack2
- Top Cx13A @ DAL713-4WI

➢ Objectives

- Viscosified water sampling (water injected in DAL713) to measure viscosity, concentration, and salinity
  - ➔ MDT sampling,
  - ➔ Bottom hole sampling,
- Well later converted to a Producer Cx8 and Cx3

➢ Challenging Operations

- Well was side-tracked (cased hole) after MDT water sampling.
- Two Side Tracks due to clay instabilities
- Side Track 2 completion is now in place.

➢ Viscosified water sampling

- MDT samples July 2011
  - Collected from Cx13A / Cx13B and Cx12A
  - Presence of polymer confirmed in expected concentration,
  - Inconclusive viscosity results
- BHS samples (side track 2)
  - Delayed to July 2012 because of operational issues on well completion
  - Viscosity in line with expectation

➢ Producer for Cx3 & Cx8

- Very good oil bearing sand intersected at the base

CONCLUSIONS

- **The sampler well is a success**
  - Sampling of polymer in the swept area
  - Producer well for bottom reservoirs

- **Thank to 4D seismic we have been able :**
  - To prognose the extension of water
  - To update reservoir model for fitting 4D
  - To detect unproduced layers

- **Extension of polymer injection to the entire field is planned for 2014**

- **This is a full multidisciplinary work**


THANK YOU
for your attention