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4D WORKFLOW WITHIN TOTAL GROUP

Henri HOULLEVIGUE, Christian HUBANS

OUTLINES

- 4D seismic introduction
- TOTAL workflows
  - 4D Feasibility studies
  - 4D workflow
- Conclusions
- Questions

4D SEISMIC INTRODUCTION

THE “AFRICAN SUNSET” “4D” EXPERIMENT

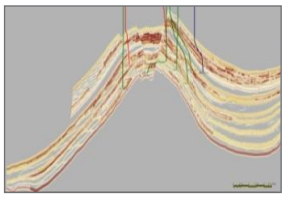
THE “AFRICAN SUNSET” “4D” EXPERIMENT

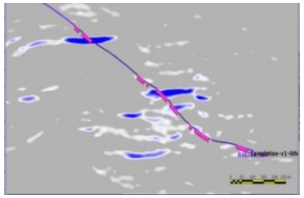
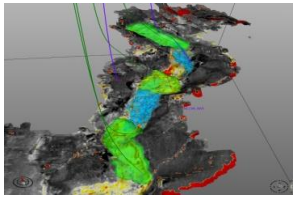
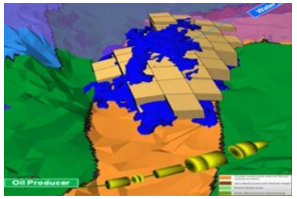
4D image difference

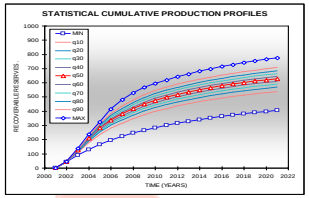
- **« 4D » is a term defining successive 1D (VSP), 2D or 3D seismic experiments**
- **The quality of a 4D result is limited to the quality of the baseline survey (since the monitor survey is often of better quality)**
- **4D is based on a physical measure depicting complex processes, physical measure having its own limits…**

4D WORKFLOWS WITHIN TOTAL

4D TOTAL WORKFLOW





4D feasibility | 4D acquisition & processing | 4D warping & inversion | 4D interpretation | 4D integration into geomodels | 4D History Match

- **4D Rock Physic Model:** to compute density and velocity variations according to a description a rock, fluids and production phenomena.

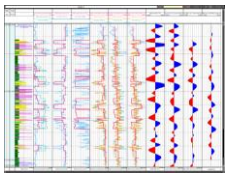
- **4D signal feasibility:** to compute 4D signal (dV/V, time shifts, amplitude changes) related to production phenomena.

- **4D acquisition feasibility:** to assess the best design for the best 4D repeatability.

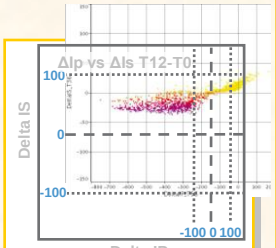
4D SEISMIC FEASIBI

4D feasibility

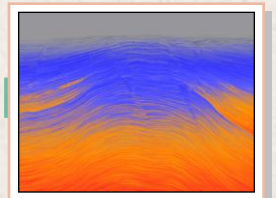
Petroelastics



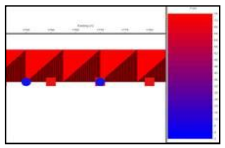
Rock Physics Model : (V_P, V_S, ρ)=f(petrophy)



Petroelastic behaviour analysis

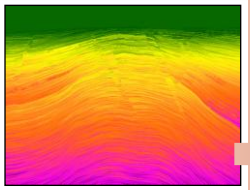


Building a realistic overburden

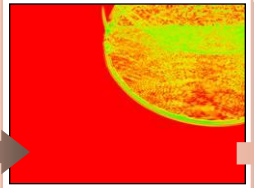


A priori seismic acquisition design

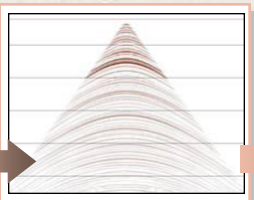
Fullwave modelling



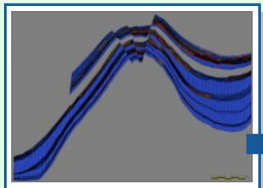
Regular « elastic » grid (V_P, V_S, ρ_B)



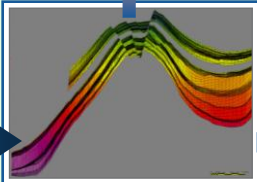
Seismic modelling (2D fullwave)



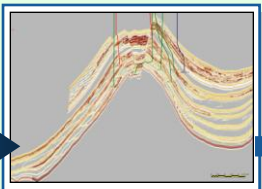
Synthetic seismic pre-processing



Reservoir grid (Φe, NTG, Swe, Soil, Sgas, pressure)

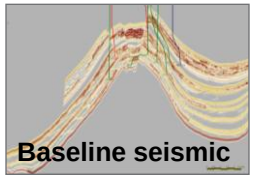


« Elastic » grid (V_P, V_S, ρ)

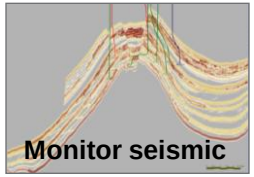


Multi 1D convolutional modelling

Convolutional

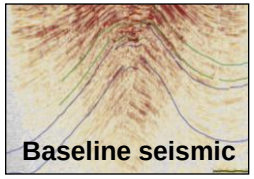


Baseline seismic

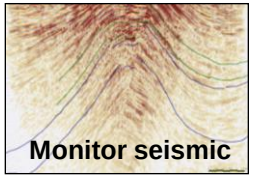


Monitor seismic

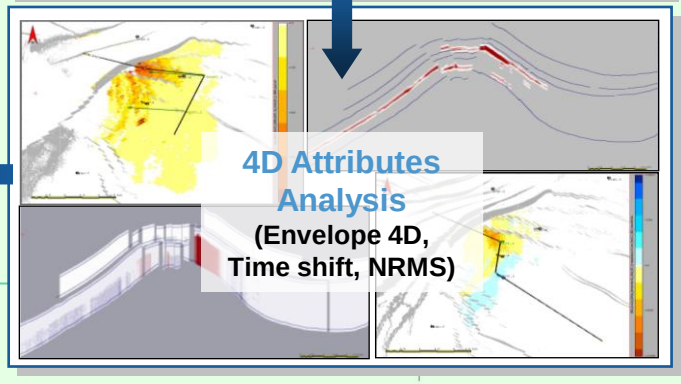
Fullwave



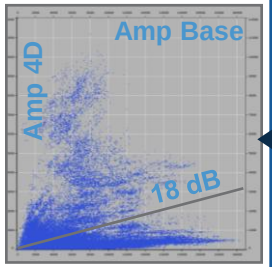
Baseline seismic



Monitor seismic



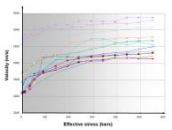
4D Attributes Analysis (Envelope 4D, Time shift, NRMS)



4D signal analysis & noise integration

Main workflow

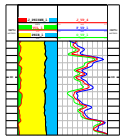
DYNAMIC ROCK PHYSICS MODEL



Core measures

+

Impact of ΔP on velocities



In situ time lapse velocity measures

+

Static RPM

+

Thermo dynamics

+

Impact of ΔS_w on velocities

+

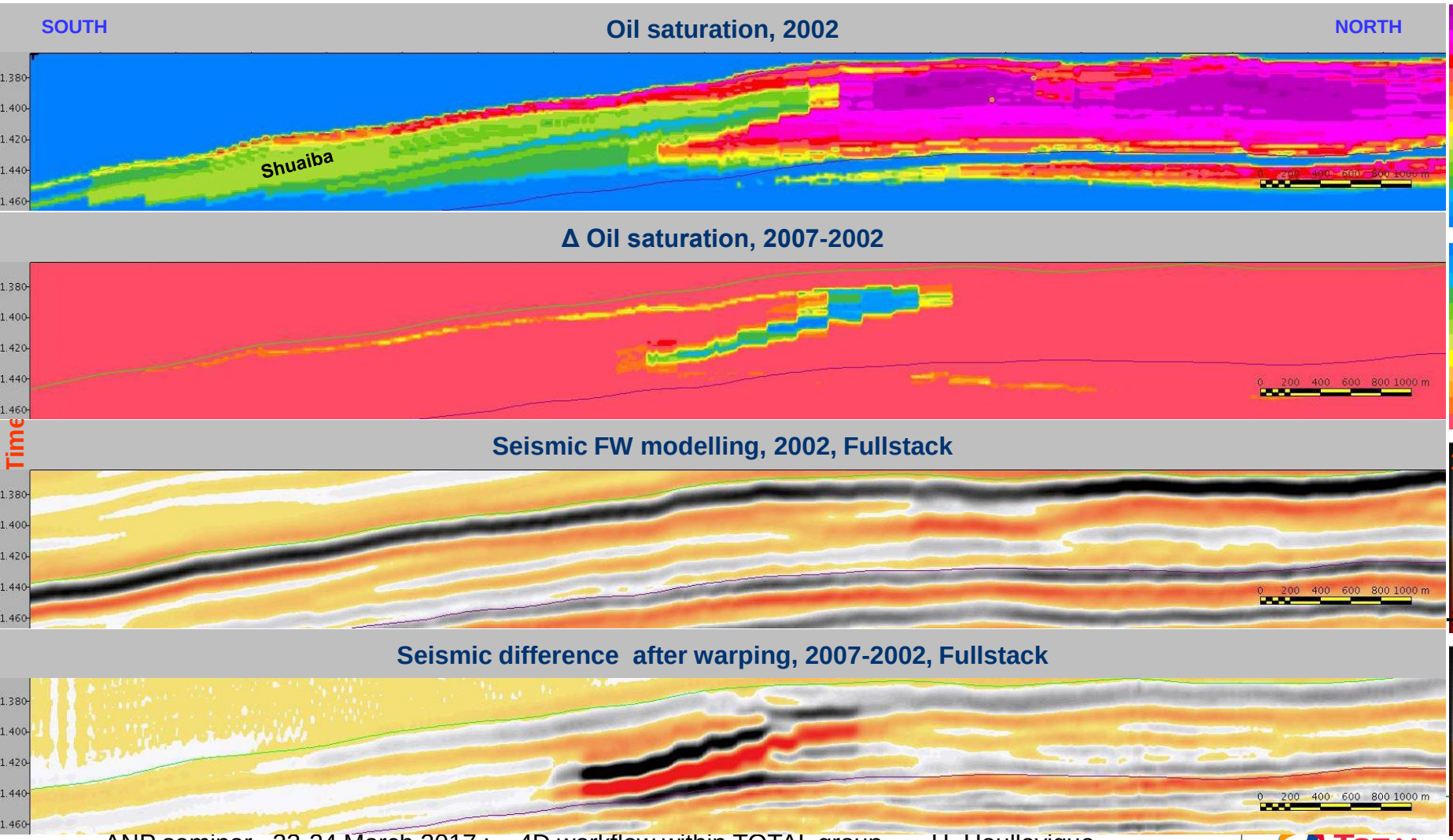
Gassman's theory

→ Dynamic RPM

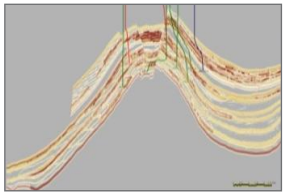
field & seismic monitoring

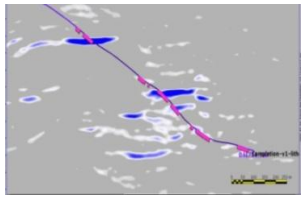
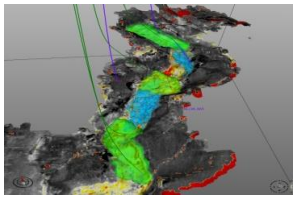
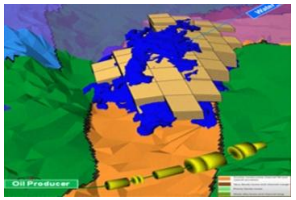
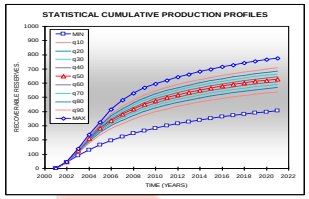
Example of 4D seismic feasibility in carbonates

Zoom on the water outbreak on carbonate reservoir



4D TOTAL WORKFLOW



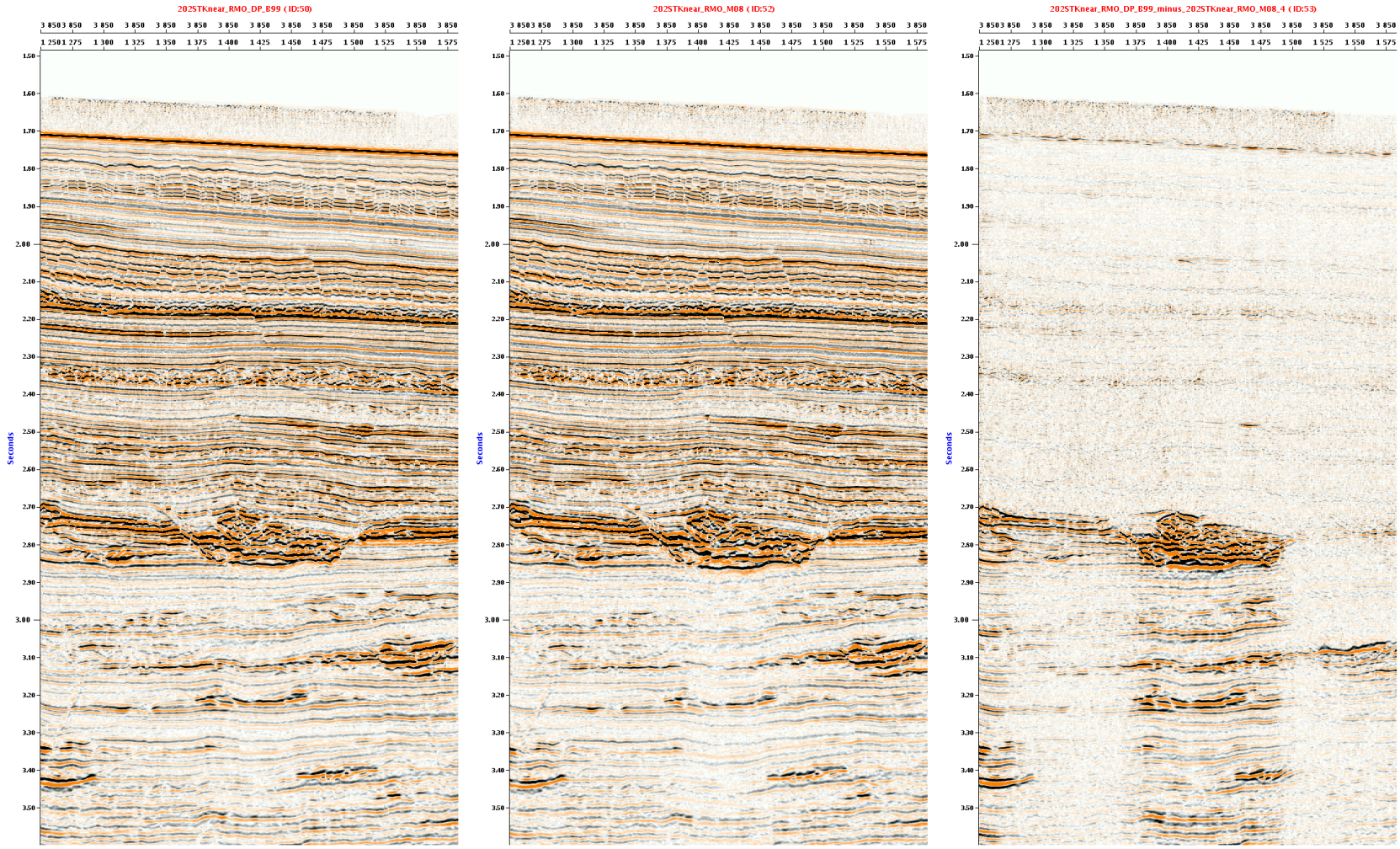





4D feasibility | 4D acquisition & processing | 4D warping & inversion | 4D interpretation | 4D integration into geomodels | 4D History Match

- 4D inversions algorithms deliver 4D attributes useful for volumetric interpretation and their integration in geomodel.
- **4D Warping:** 4D inversion of base and monitors with no a priori model which delivers 4D DV/V, time shift and warped monitor (short process: 1 month).

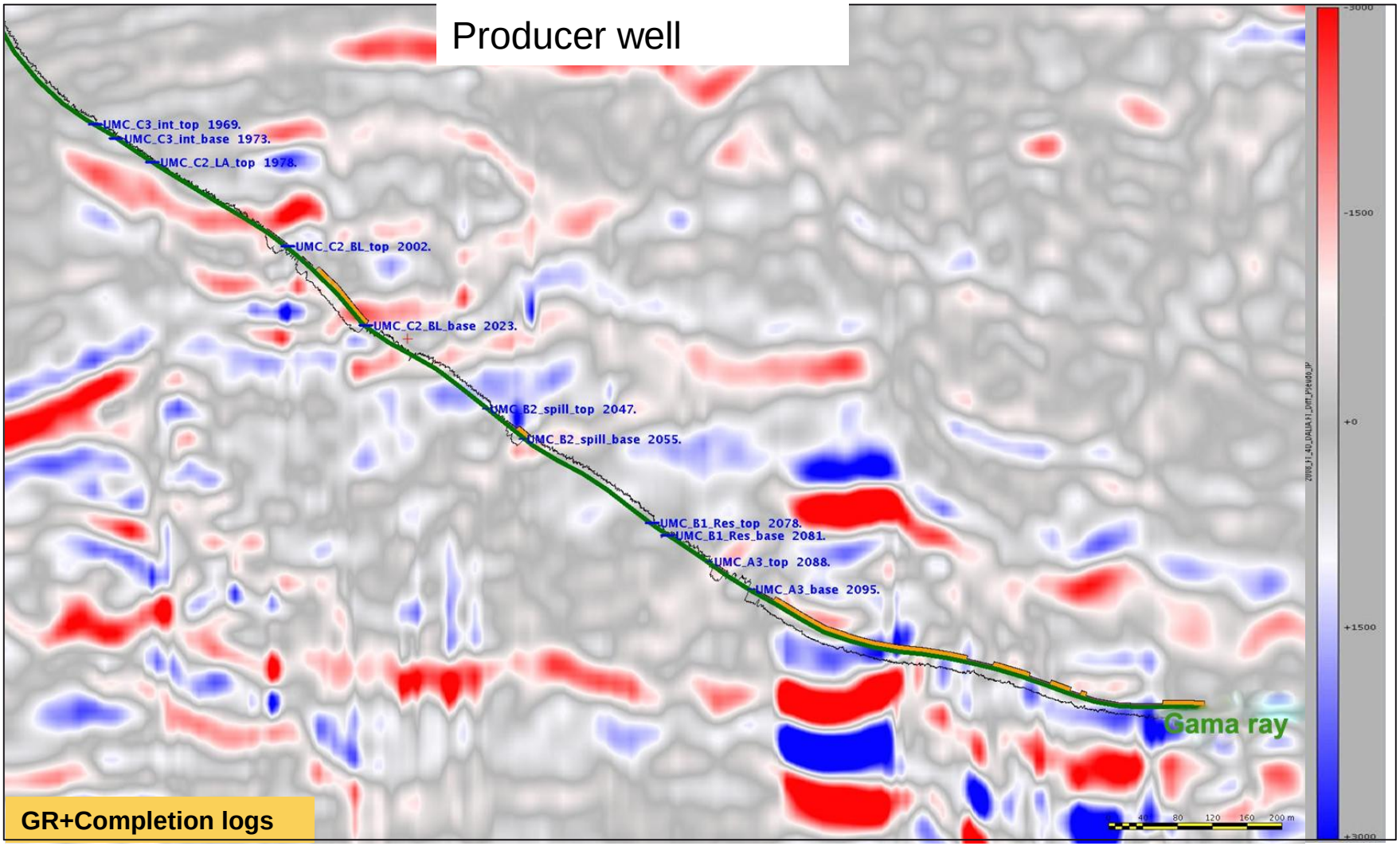
- **4D impedance inversion:** 4D inversion of base and monitor with an a priori model which delivers dIp/Ip and dIs/Is (long process: 6 months).

STACKED RESERVOIR EFFECT

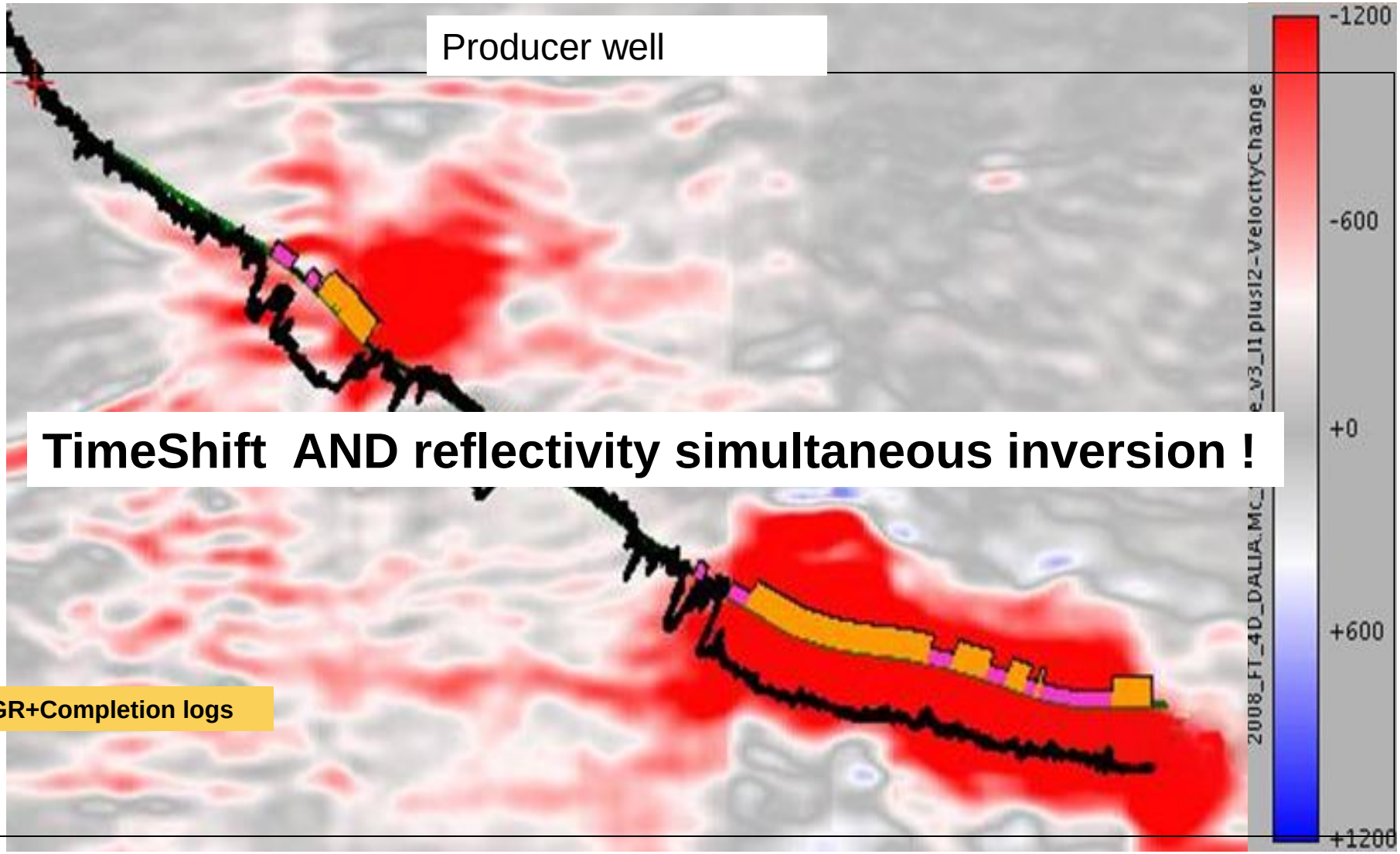


B99 M08 4D Difference

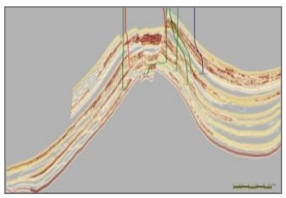
4D PSEUDO-IMPEDANCES AFTER CROSSCORR WARPING

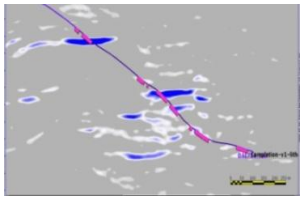
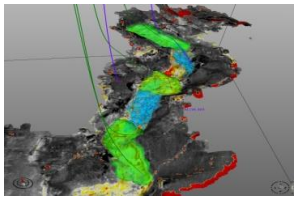
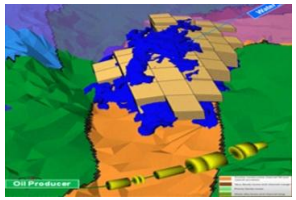
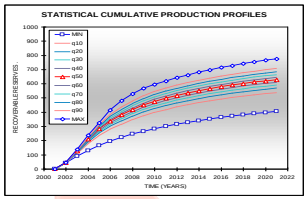


4D ΔVP/VP FROM TOTAL'S WARPING : L.F. CONTENT !



4D TOTAL WORKFLOW



4D feasibility | 4D acquisition & processing | 4D warping & inversion | 4D interpretation | 4D integration into geomodels | 4D History Match

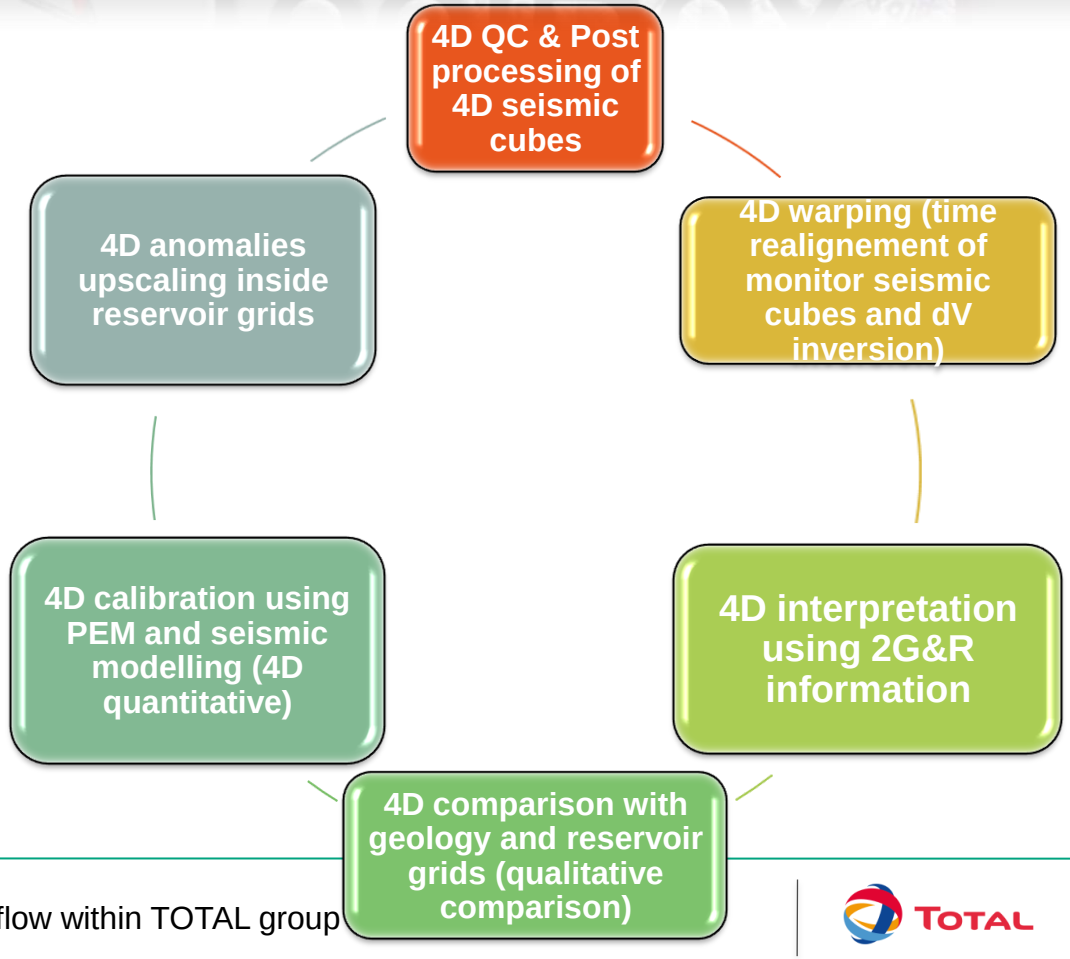
- **4D interpretation**
- Choice of best attributes to use for 4D interpretation (time shift, 4D dV/V, amplitude differences).

- Perform **4D composite maps** containing all 2G&R information: 4D, AE maps, wells info, etc.

- Several methodologies of interpretation exist: picking of seismic horizons, 4D boundaries and **4D geobodies** (3D envelope of 4D attribute changes).

4D INTERNAL & INTEGRATED SOFTWARE TOOL SISMAGE

- SISMAGE 4D tool box
  - 4D QC
  - 4D inversion
  - 4D interpretation in volumetry & multi-cube
  - 4D calibration
  - 4D seismic modelling from wells & reservoir grids
  - 4D petroelastical modelling
  - 4D upscaling inside reservoir model

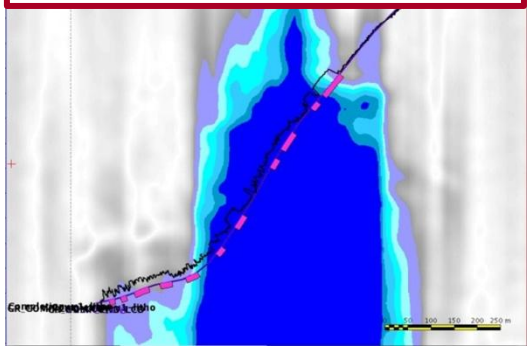


DIFFERENT ATTRIBUTES FOR 4D INTERPRETATION

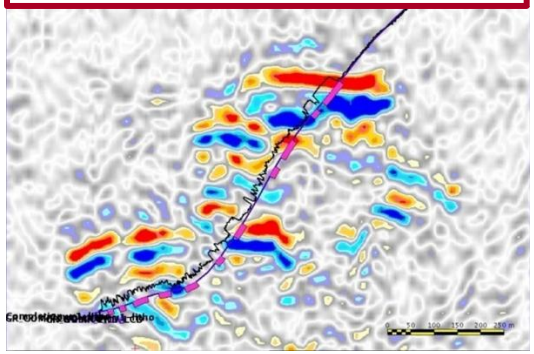
- Seismic attributes must be tested:
  - > dV/V attribute issued from warping
  - > Monitor – base seismic amplitude
  - > Monitor – base envelopes
  - > Time shift attribute
  - > dIp/Ip (Ip monitor – Ip base)
- No magic attribute ! But different ways to detect production phenomena.

  Related to Seismic quality...S/N...etc

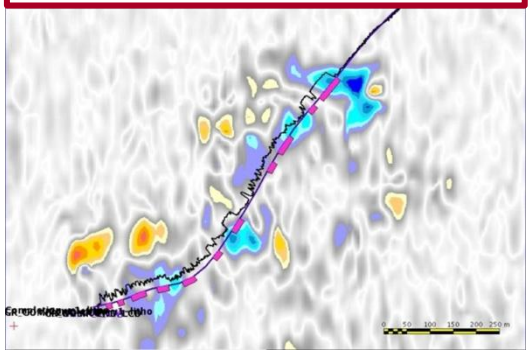
Time shift in ms



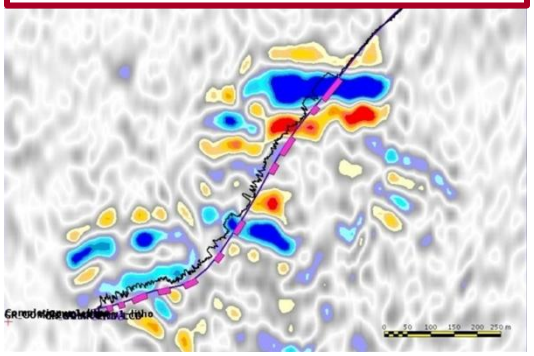
Amplitude difference



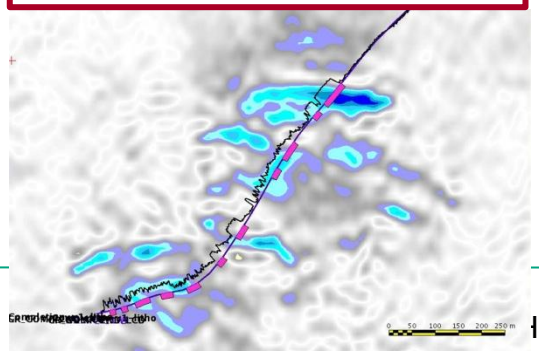
Difference of amplitude envelopes



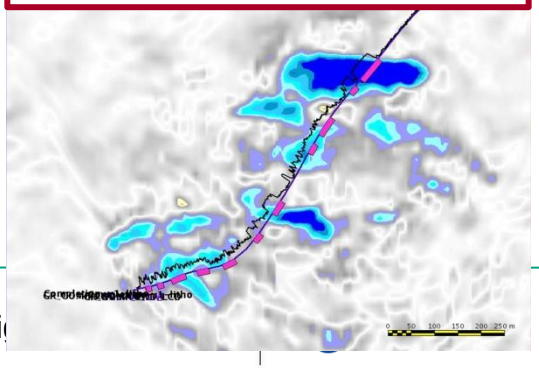
Difference of pseudo impedances



dV/V



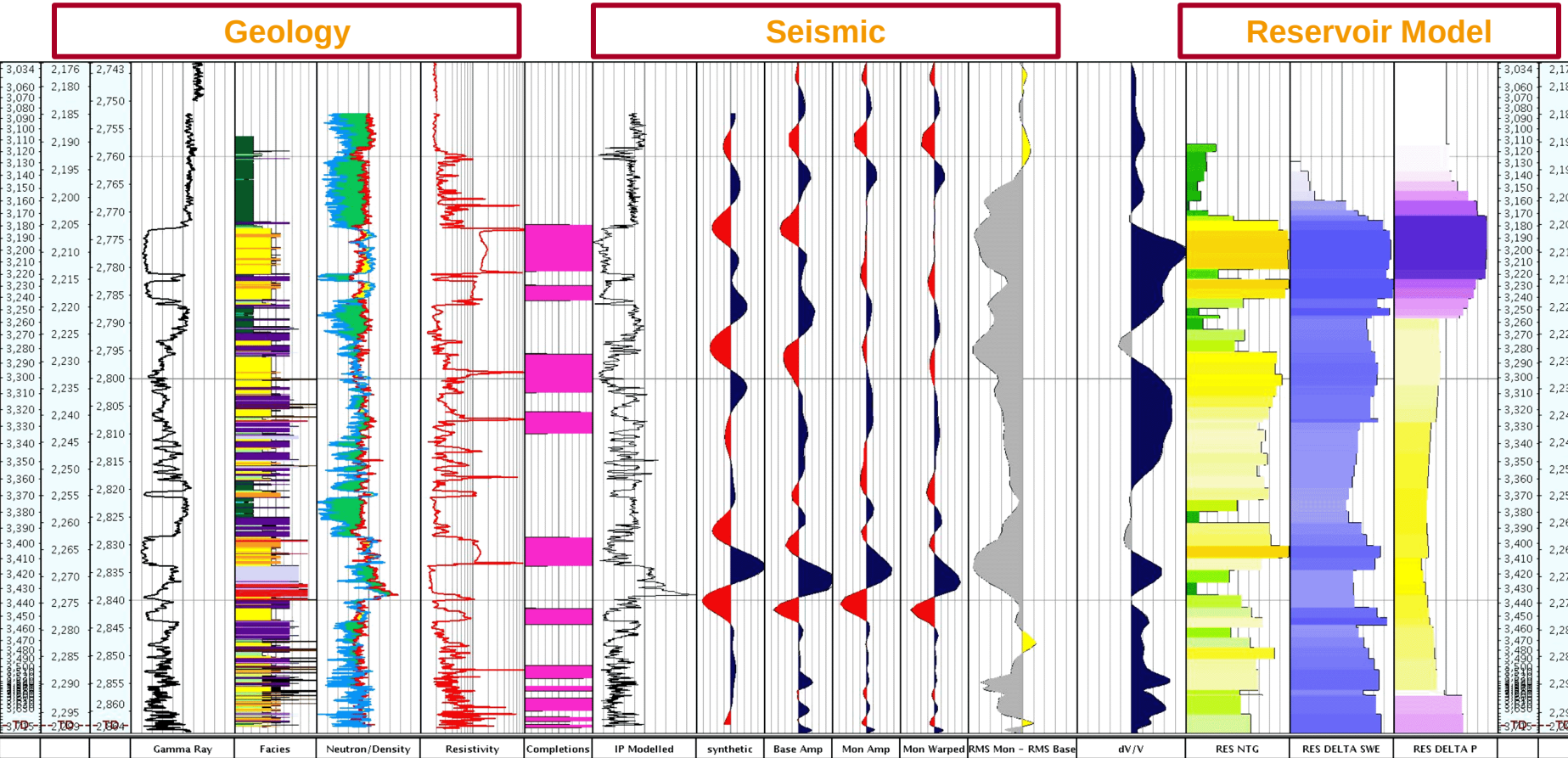
dIp/Ip



4D WELL CALIBRATION

3G calibration template for 4D and reservoir consistency

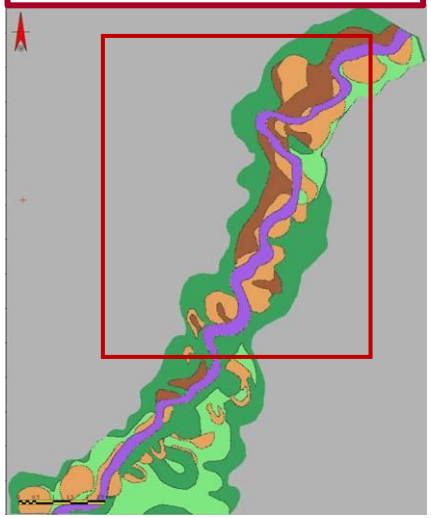
- Geological data: GR, Facies, Resistivity, Neutron/Density
- Geophysical data: sonic and synthetic data, base amplitude trace, monitor amplitude trace, RMS amplitude difference, dV/V attribute, dIp/Ip
- Reservoir data: Delta Sw, delta Sg, Delta P coming from Eclipse reservoir simulation.



4D COMPOSITE MAPS

- Creation of composite maps with all useful interpretation than can be shared by 3G people

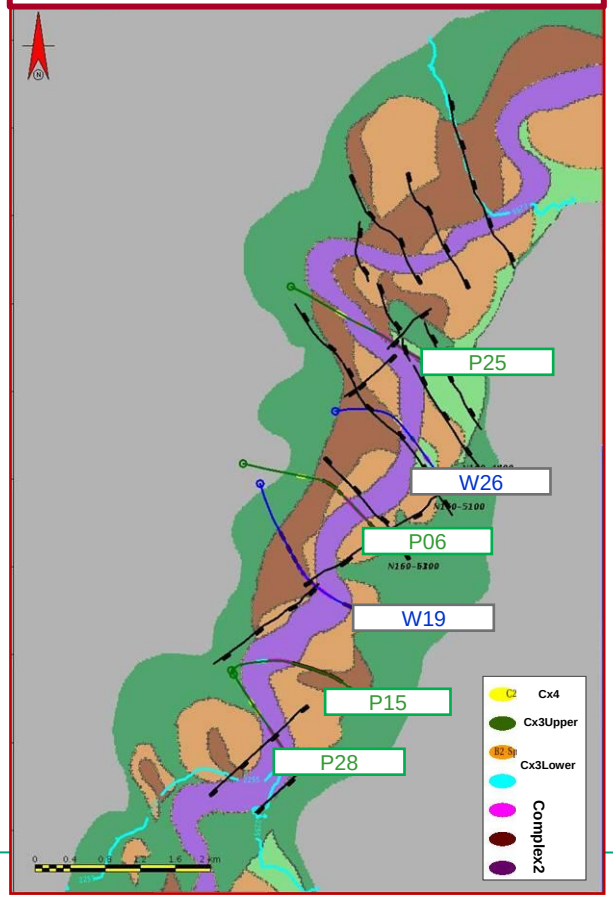
AE map



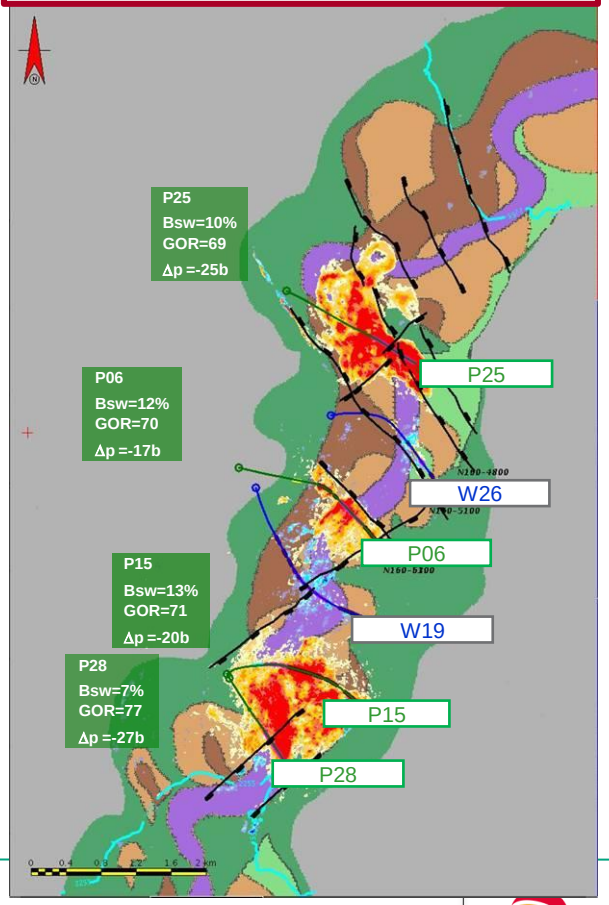
AE Legend :

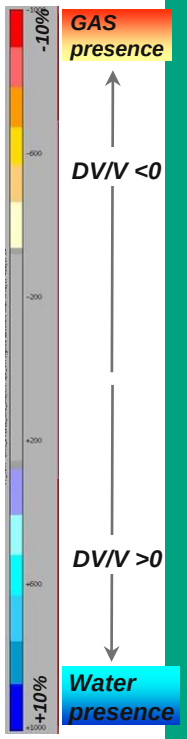
- AE 16 Injected zone - NTG 2-10-20%
- AE 8 Downgraded basal channel complex - NTG 0-10-40%
- AE 6 Erosive-constructive channel fill & lateral accretion - NTG 60-70-90%
- AE 4 Very sandy levee & channel margin - NTG 30-40-60%
- AE 3 Poorly sandy levee - NTG 5-15-30%
- AE 2 Shaly silty levee - NTG 0-2-5%

With Wells Development, Fault boundaries, and OWC@2255mss



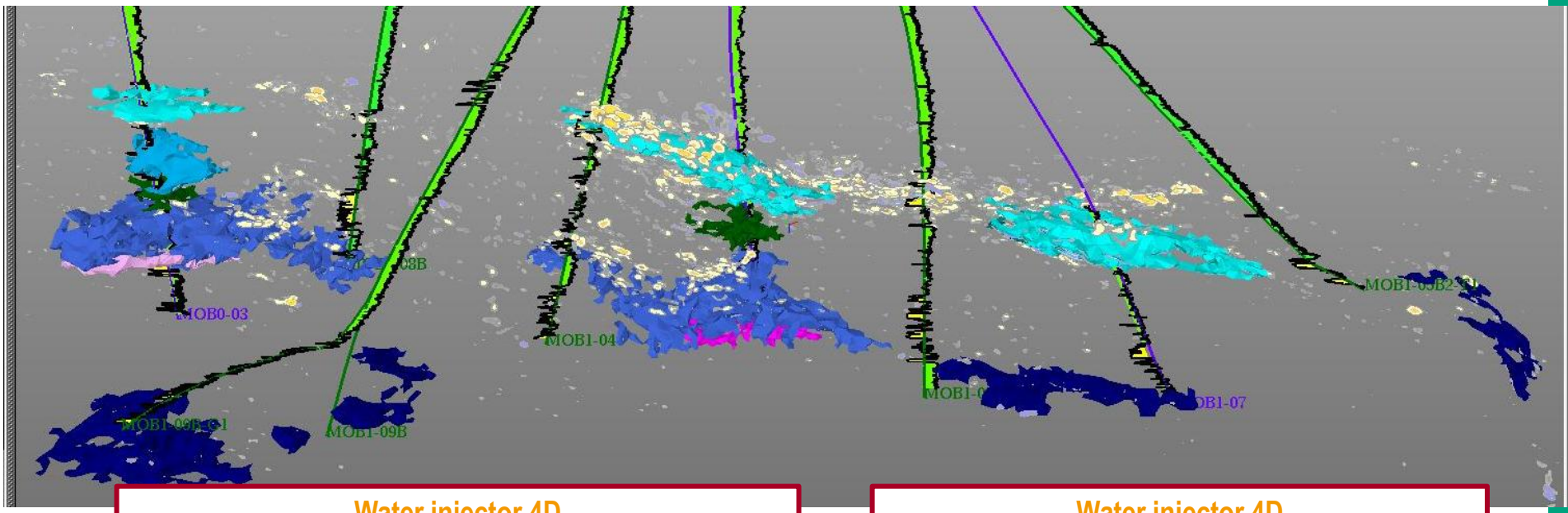
With 4D Full Proc. DV/V Signed ABS max



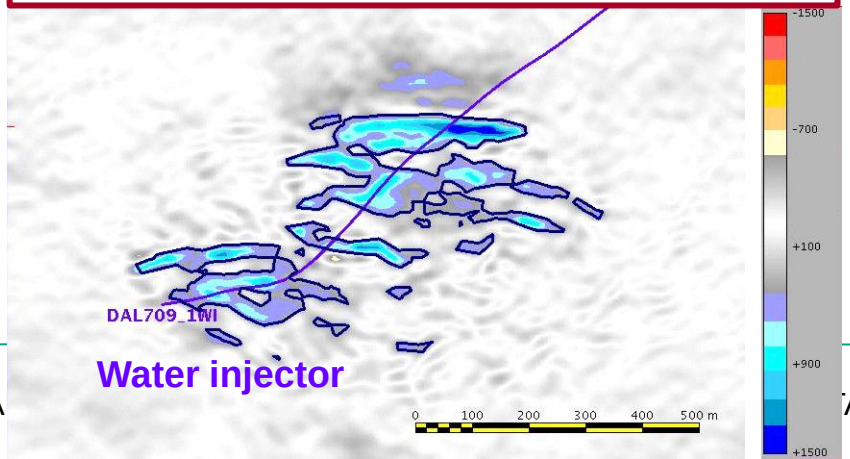


4D INTERPRETATION TROUGH GEOBODIES TECHNIQUE

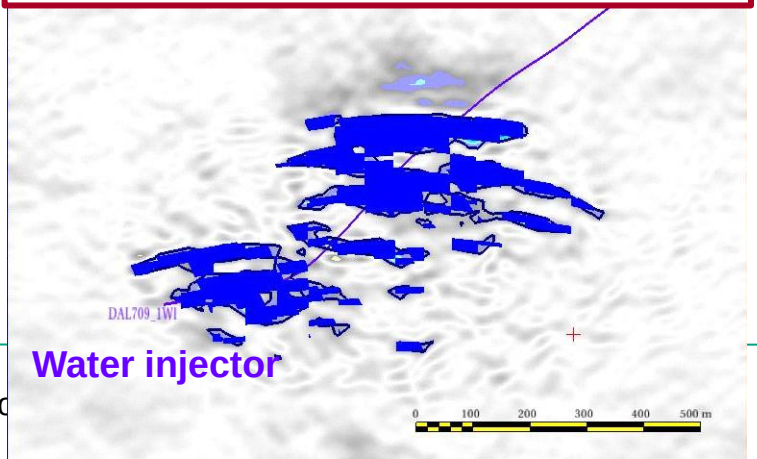
- 4D geobodies propagators were developped in SISMAGE



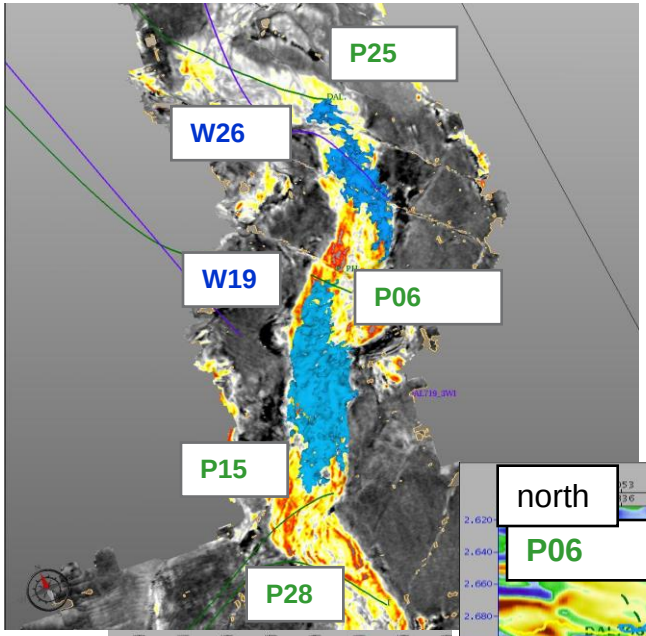
Water injector 4D geobody seismic scale



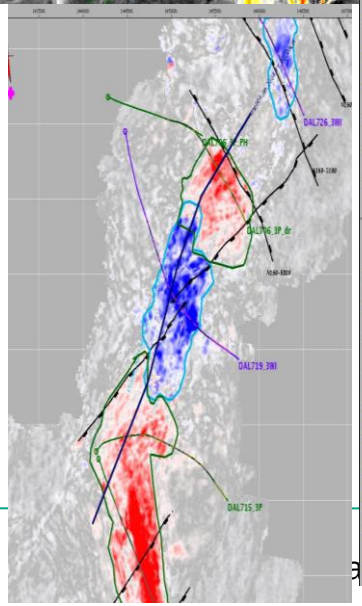
Water injector 4D geobody geomodel scale

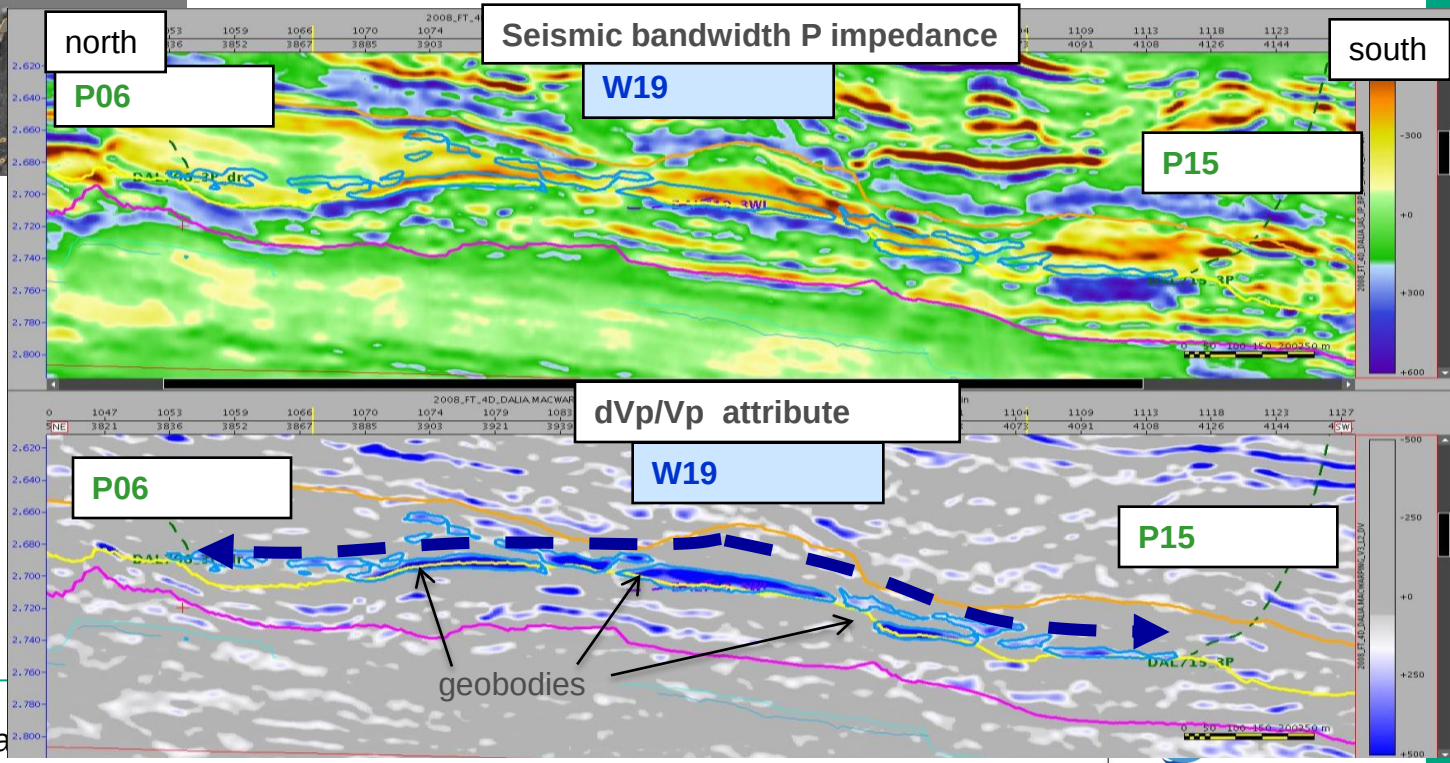


4D & 3D INTERPRETATION: WATER INJECTION EFFICIENCY

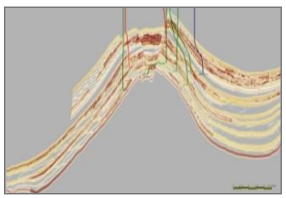


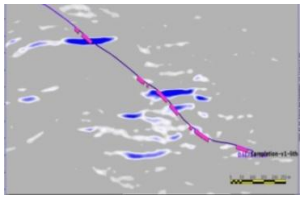
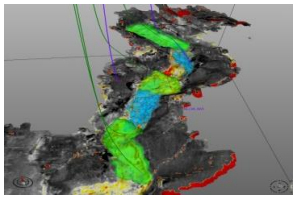
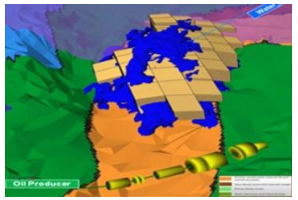
Geobodies are picked on dV/V cube then
➔ checked onXsection
➔checked on seismic facies
➔ used to interpret water path…

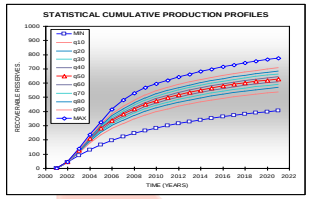




4D Total workflow





4D feasibility | 4D acquisition & processing | 4D warping & inversion | 4D interpretation | 4D integration into geomodels | 4D History Match

1- 4D integration for static model update

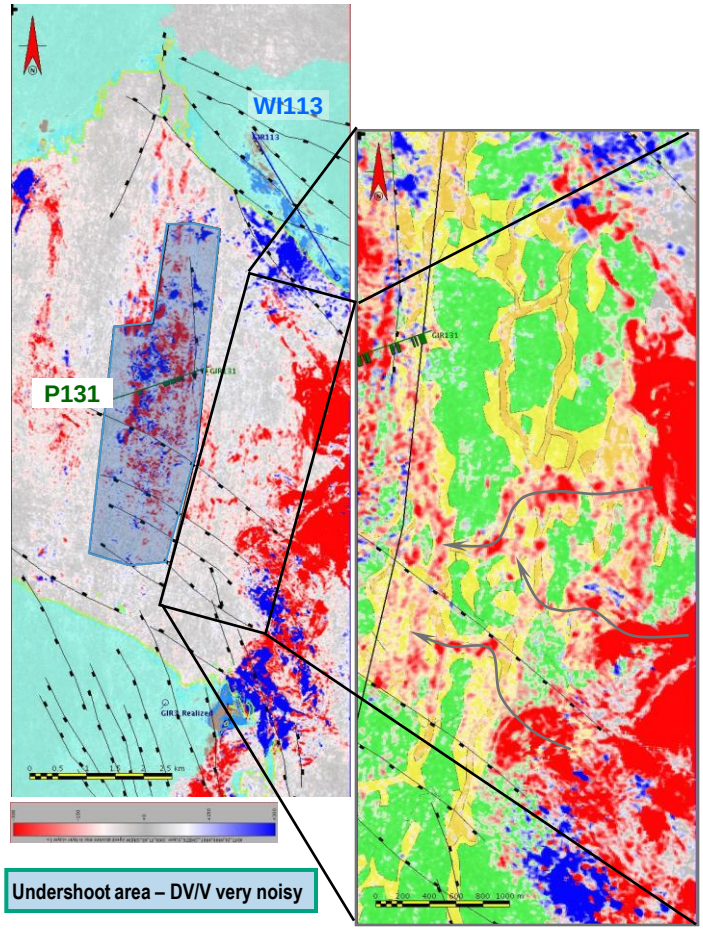
- Use of 4D for sedimentological model update: facies maps are compared to 4D extensions and help to update facies limits.
- Use of 4D as facies modelling guide and for petrophysical infilling quality control.

2- 4D integration for dynamic model update

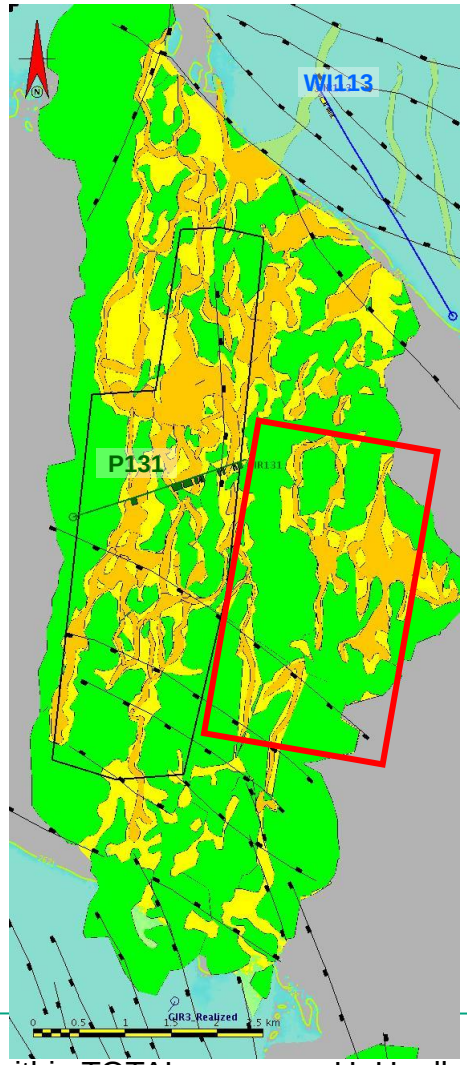
- Geological heterogeneities characterization
- Dynamic Aquifer behaviour.
- 4D injected/produced volumes computation.

EXAMPLE OF SEDIMENTOLOGICAL MODEL UPDATE

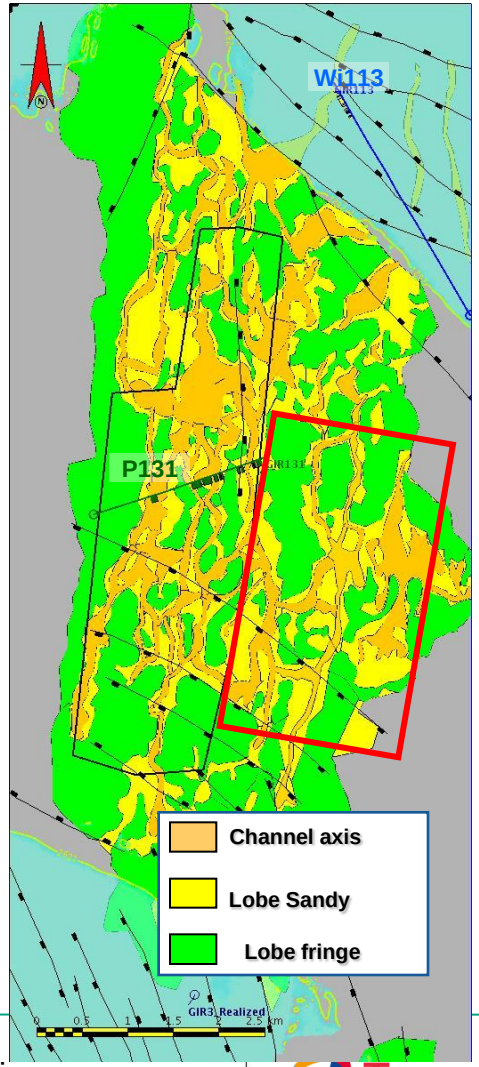
4D DV/V



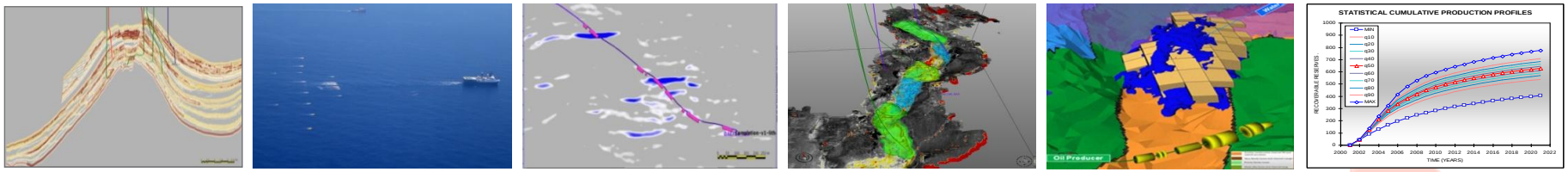
Initial facies map



Revised facies map following 4D info



4D Total workflow



4D feasibility | 4D acquisition & processing | 4D warping & inversion | 4D interpretation | 4D integration into geomodels | 4D History Match

1- 4D seismic integration for 'dynamic synthesis'

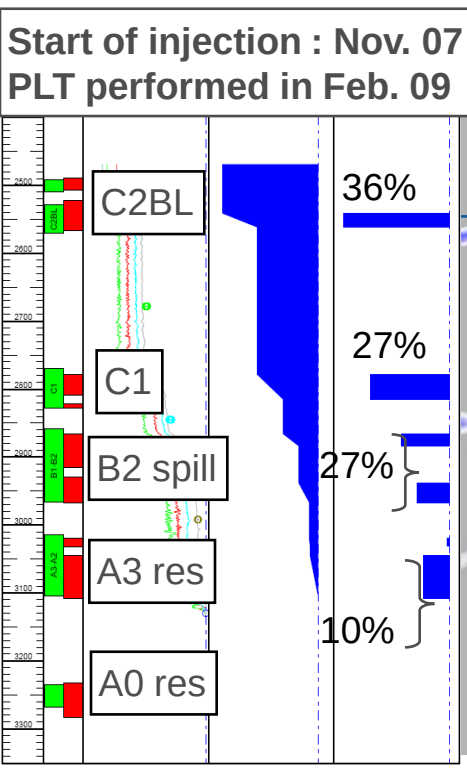
4D geobodies ⇔ compute the injection split per complex for co-mingled injectors

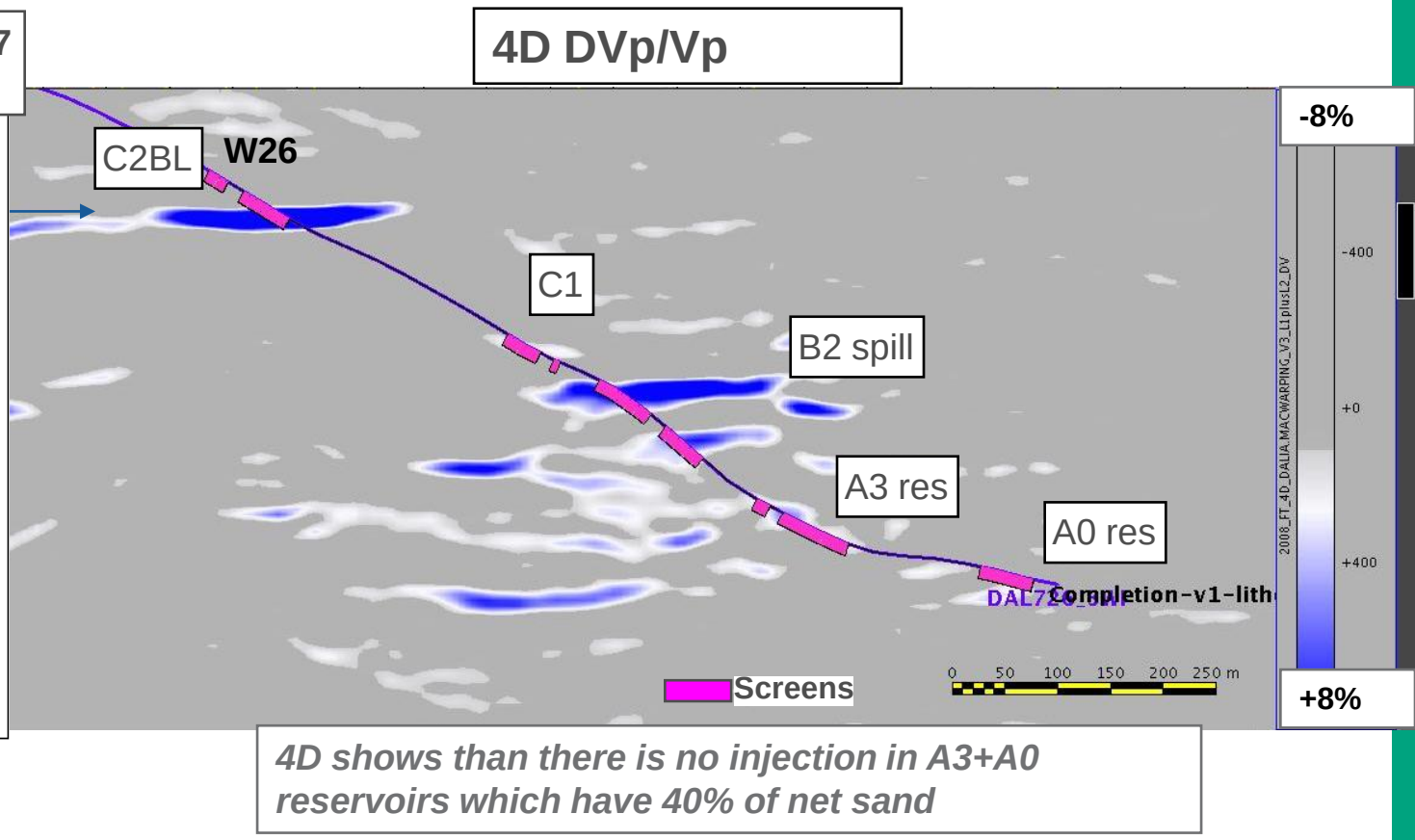
⇔ integration with well monitoring data

2- 4D seismic derived indicators for History Matching

From 4D 'water injection', 'gas ex-solution' and 'WOC rise' geobodies can be input to the simulation models to compute '4D seismic vs. simulation' mismatch indicators.

4D AS A SEISMIC PLT





4D shows than there is no injection in A3+A0 reservoirs which have 40% of net sand

- ***PLT data shows water injected at one instantaneous moment***
- ***4D shows water injected over a longer period (in qualitative way)***
- ***Both measurements should not be in disagreement, 4D can shows wells or reservoir evolution through time***
- ***In wells without PLT information, 4D should help understanding water injectivity.***

CONCLUSIONS

- 4D seismic is now a proved and valuable technique.
- TOTAL considers 4Dseismic mandatory in new field development.
- TOTAL has a large and wide experience in 4D seismic :
  - Acquisition & Processing team with various experiences looking for cost adapted solution and target adapted solution.
  - Various TOTAL's Interpretation workflows :
    - from fast track route to detailed quantitative interpretation and History Match
  - 4D Feasibility studies and 4D pilot.
- TOTAL specific in-house tools. *(Processing,Warping, well tie, H.M...)*
- TOTAL is organized for true transverse interpretation through Transverse team and common workstation.
- 4D seismic is THE TOOL to detect unexpected phenomena on a field
  - But this request large collaboration 2G&R, + petrophysicist, geomechanics, PVT...etc..

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