3D Static and Dynamic Modeling of a Clastic Multilayered Reservoir with Heavy Oil: a Case Study from Comodoro Rivadavia Formation in El Alba Valle Field (Manantiales Behr Block, Golfo San Jorge Basin, Argentina)*

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Abstract

The primary goal of this study was to determine the optimum approach - either water or polymer flood- for exploitation of El Alba Valle field. Historically the methodology used in these types of reservoirs for field development was based on the correlation of individual sandstone bodies, assuming no lateral or vertical connectivity between them. Applying this methodology, STOIIP calculations were highly conservative, pay being calculated exclusively from sands that produced oil from short-duration tests. Additionally if the sands were indeed isolated, this would have a negative impact on the potential effectiveness of any improved oil recovery (IOR) strategy.

This work presents the integrated 3D static and dynamic reservoir characterization and modeling of the Comodoro Rivadavia Formation, a 45% net-to-gross (NTG), ~500m thick succession interpreted as a multilateral and multistory fluvial system. Characterization of this reservoir is challenging due to the fact that is multilayered, with very heterogeneous sandstone bodies and multiple fluid contacts. There is only a limited set of well logs (SP, RES and DEN) and no core available. The absence of reliable production logging tool (PLT) measurements makes geological interpretation and dynamic validation the only way to estimate which sandstones are in fact oil-bearing in the medium-long term. Additionally flow tests in the past have been proven to be unreliable: wells with water-bearing tests have subsequently produced dry oil.

A new correlation scheme was built, dividing the reservoir into 12 units using the main shaly intervals (minimum energy in the system) as stratigraphic markers due to their continuity across the field. These shaly intervals act as boundaries between which sandstone bodies are grouped together into a flow unit with a single oil-water contact. This approach was tested by dynamic simulation and found to provide a match and explanation of historical production and pressure behavior, thus supporting the proposed fluvial architecture.

This integrated model was the first 3D static model in the history of the Block that was tested through dynamic simulation. The resultant model tripled the previous STOIIP, and has enabled a number of improved oil recovery schemes to be considered and the initial results from the waterflood pilot currently ongoing on the field to be evaluated.

Reference Cited

Fitzgerald, M.G., R.M. Mitchum, M.A. Uliana, and K.T. Biddle, 1990, Evolution of the San Jorge Basin, Argentina: AAPG Bulletin, v. 74/6, p. 879-920.

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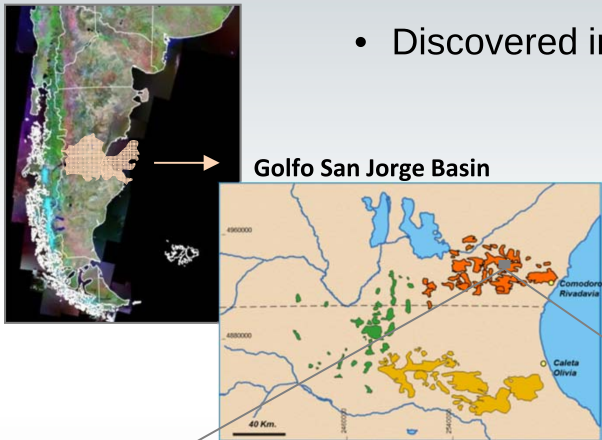
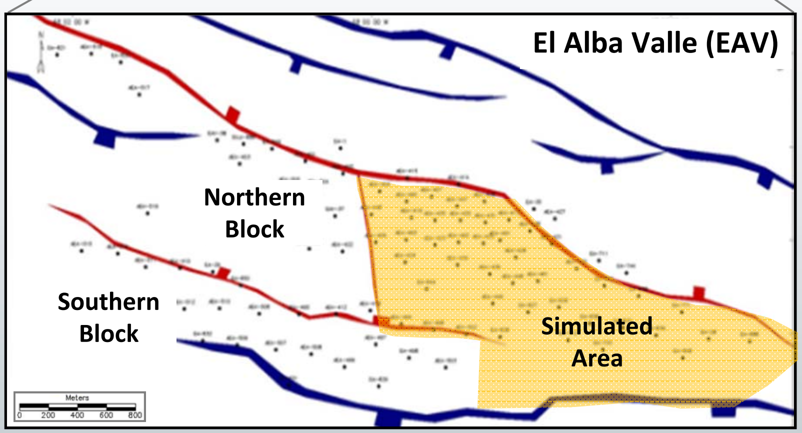
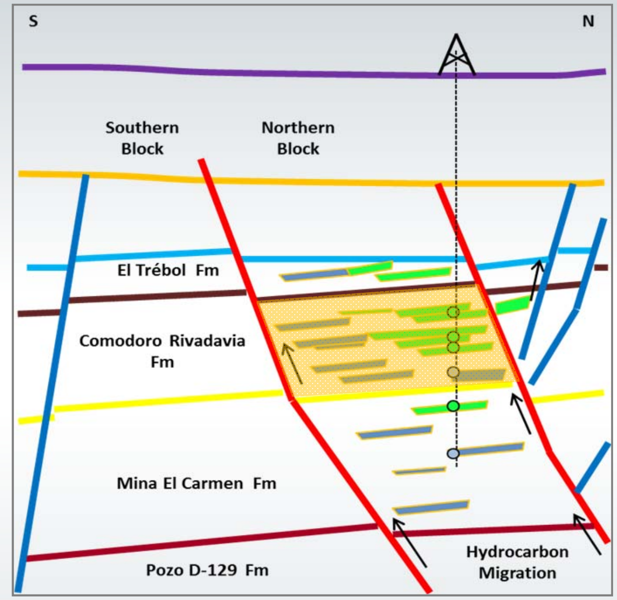
EL ALBA VALLE FIELD



- Discovered in 1960. In production since 1980
- ~ 50 wells
- Viscous oil (~180cP)
- Density 0.94g/cm3
- Oil rate ~ 5m^3/d
- Watercut 75 %





- Homoclinal structure (1° SE) bounded by faults
- Structural - stratigraphic trap
- Multilayered reservoir, 500m thick, 45% NTG (multilateral/multistory fluvial system)

OBJECTIVE: WATER OR POLYMER?

Water Pilot

STANDARD METHODOLOGY

- **Correlation of individual bodies**

(homogeneous; no lateral/vertical connectivity)

- **Conservative STOIIP calculations**

(from sandstones that proved oil in short-duration tests)

If sandstones are isolated

what would be the effectiveness of any IOR strategy?

CHALLENGES

Multilayered reservoir, 500m thick, highly heterogeneous, multiple contacts

Comingled production and absence of PLTs

Limited set of logs and core data

Short-duration flow tests

Lack of water response

NEW APPROACH

- **Correlation of genetic units**

(lateral/vertical connectivity; same FWL; internal heterogeneity)

- **More than tripled STOIIP**

(from all sandstones above FWL, according with rock quality)

DYNAMIC SIMULATION

Static-dynamic iterative process

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OUTLINE

Geological hypothesis

- Heterogeneity of sandstones bodies
- Correlation – Definition of equilibrium zones

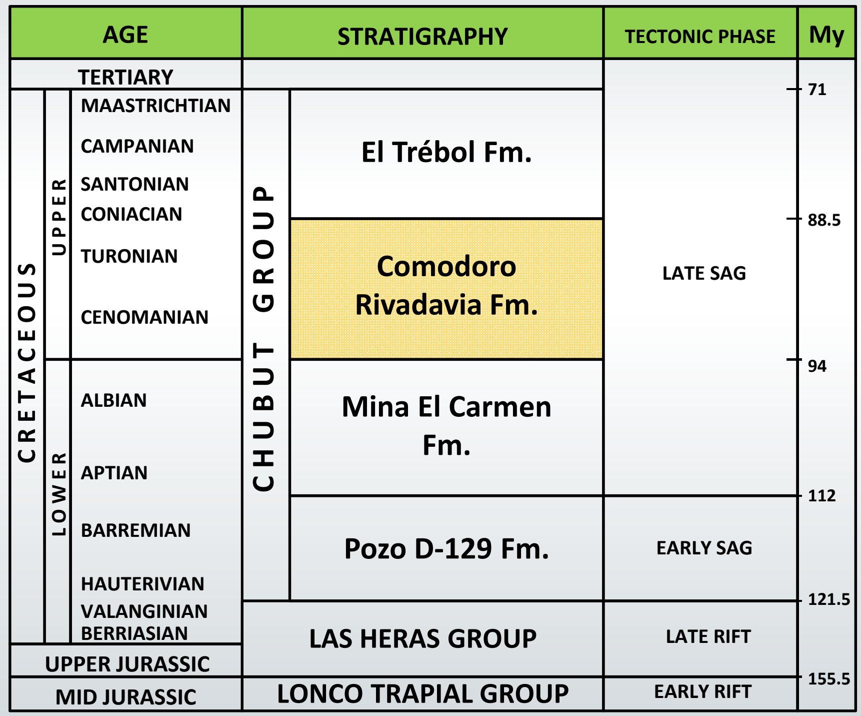
Static modeling

- Fluvial architecture
- Property modeling
- Water Saturation
- Impact on STOIIP calculations

Dynamic simulation

- Pressure matching
- Uncertainties

Conclusions



Modified from M.G.Fitzgerald *et al.* 1990

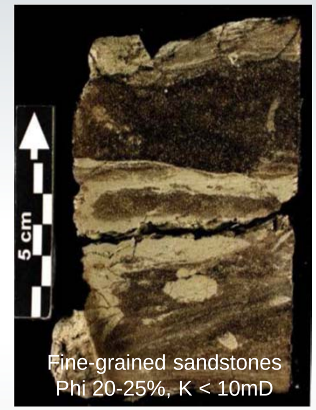
HETEROGENEITY OF SANDSTONE BODIES

✓ Heterogenous sandstone bodies

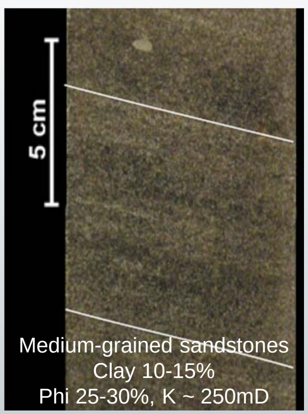
Conglomeradic sandstones
Clay < 5%
Phi 25-30%, K > 1000mD

MAIN CHANNEL FILL (BARS)

PROXIMAL FLOODPLAIN

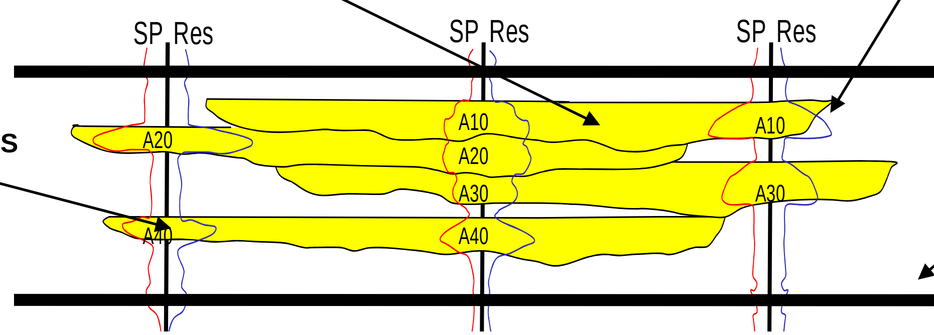


Fine-grained sandstones
Phi 20-25%, K < 10mD



Medium-grained sandstones
Clay 10-15%
Phi 25-30%, K ~ 250mD

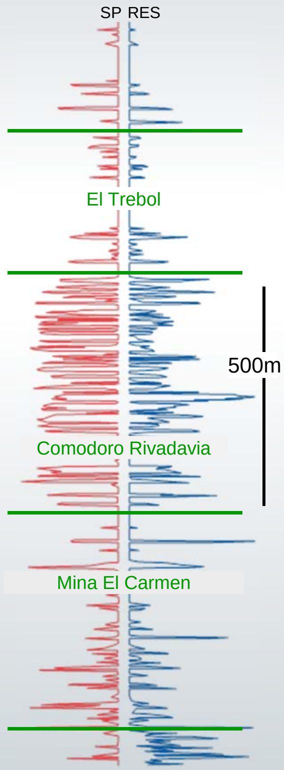
MINOR CHANNELS



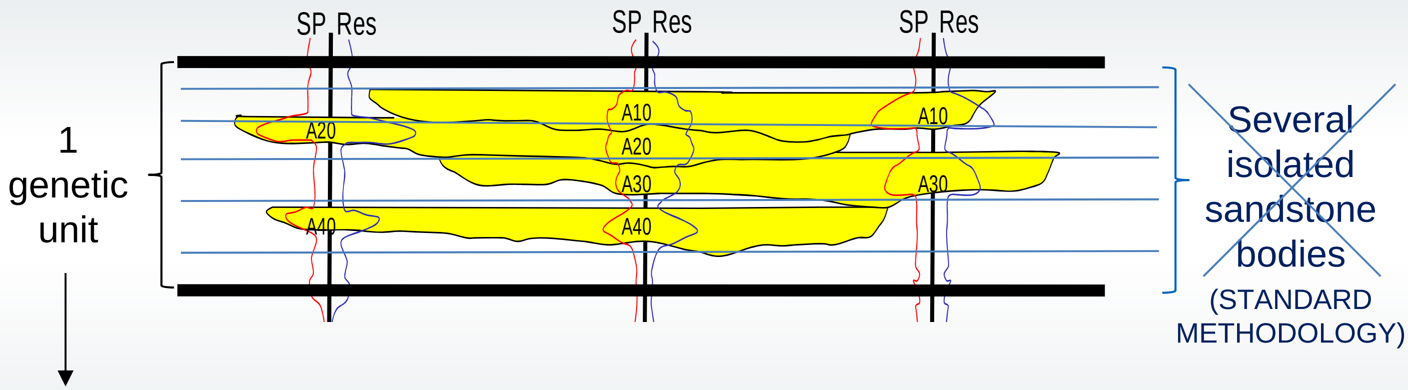
DISTAL FLOODPLAIN

Claystones, shales
K << 1mD

CORRELATION - CONCEPTUAL SCHEME



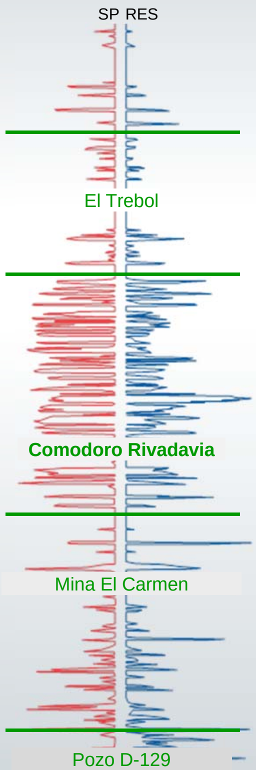
✓ Vertically/laterally connected sandstone bodies



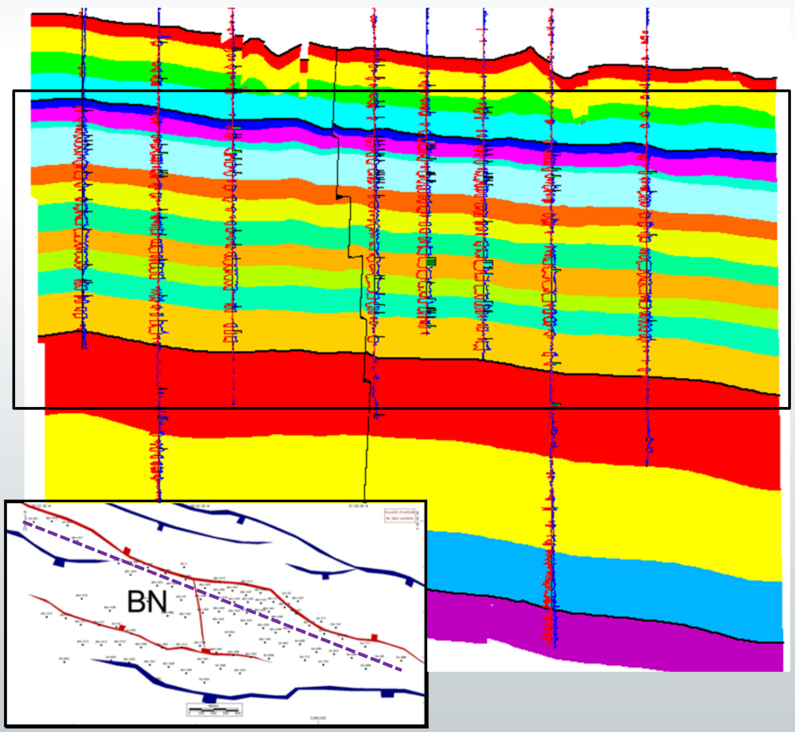
- Bounded by thick and continuous clay intervals (minimum energy)
- High connectivity assumed, based on high NTG (45%)
- Equilibrium zone with unique FWL

STRATIGRAPHY AND CORRELATION

✓ Multilayered reservoir, 500m thick, multiple contacts



- Correlation of sandstones in equilibrium zones



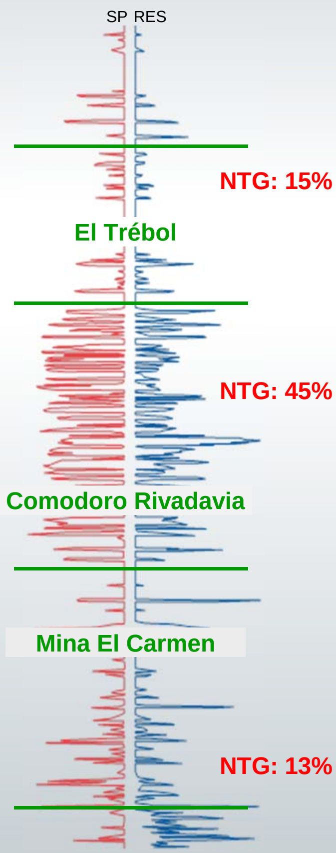
Comodoro Rivadavia Fm

12 zones

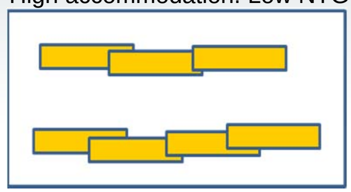
Each zone with unique FWL adjusted through static-dynamic iterations

STATIC MODEL – FLUVIAL ARCHITECTURE

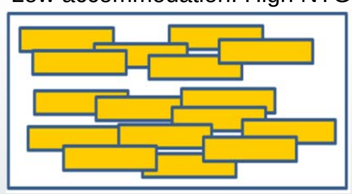
✓ Amalgamated sandstone bodies



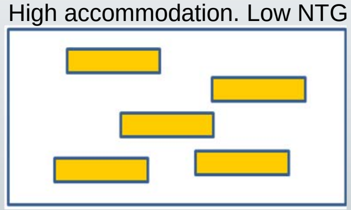
High accommodation. Low NTG

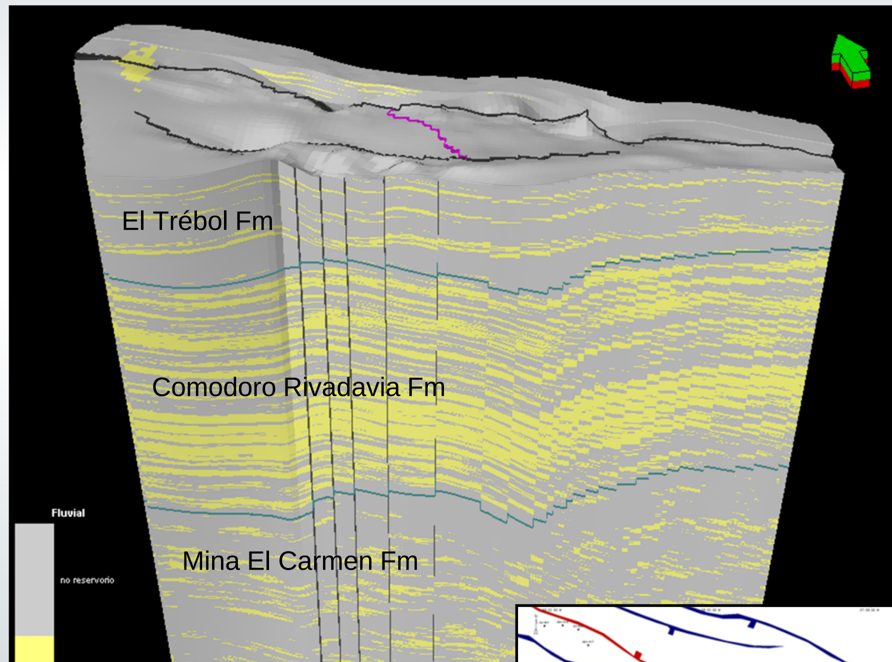


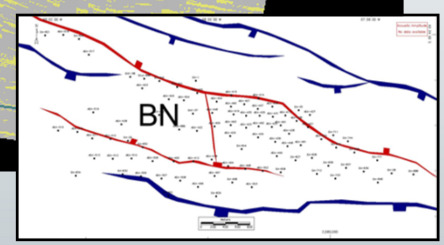
Low accommodation. High NTG



High accommodation. Low NTG







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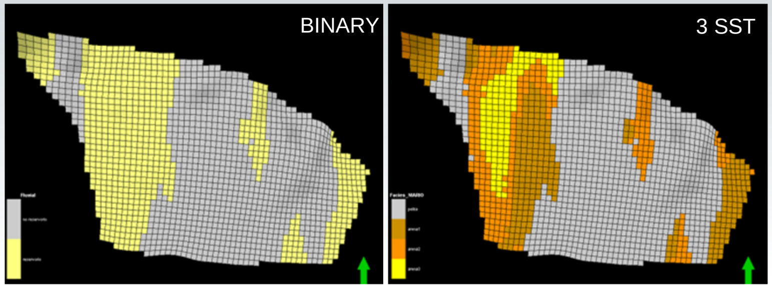
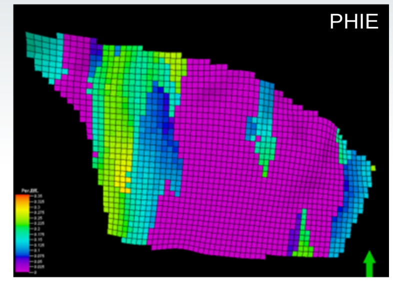
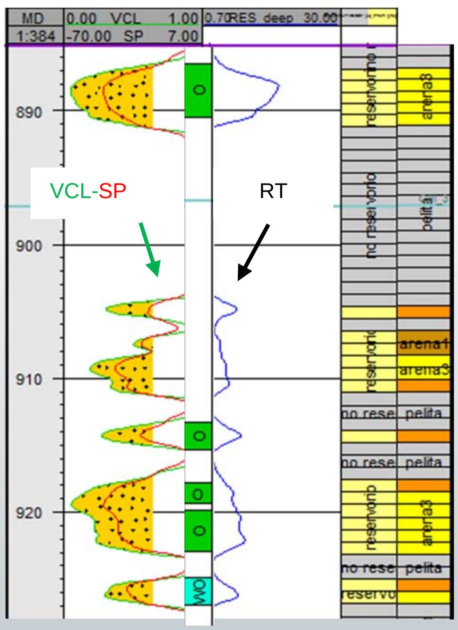
STATIC MODEL – WORKFLOW

- Definition of sandstones (VCL cutoff 0.65).
- Distribution of sandstones (definition of channel belts)

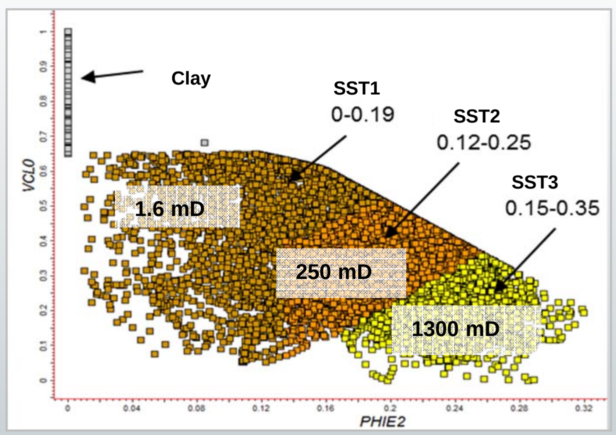


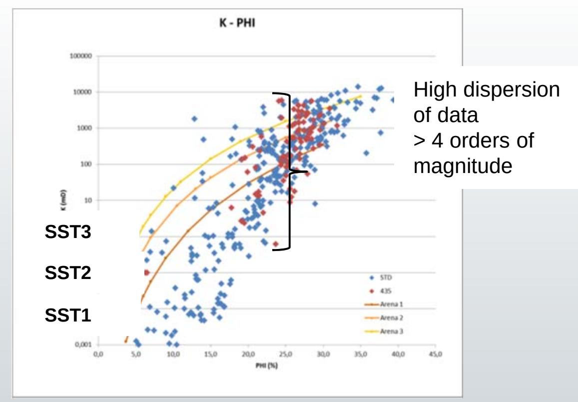
- Distribution of porosity for each type of sandstone





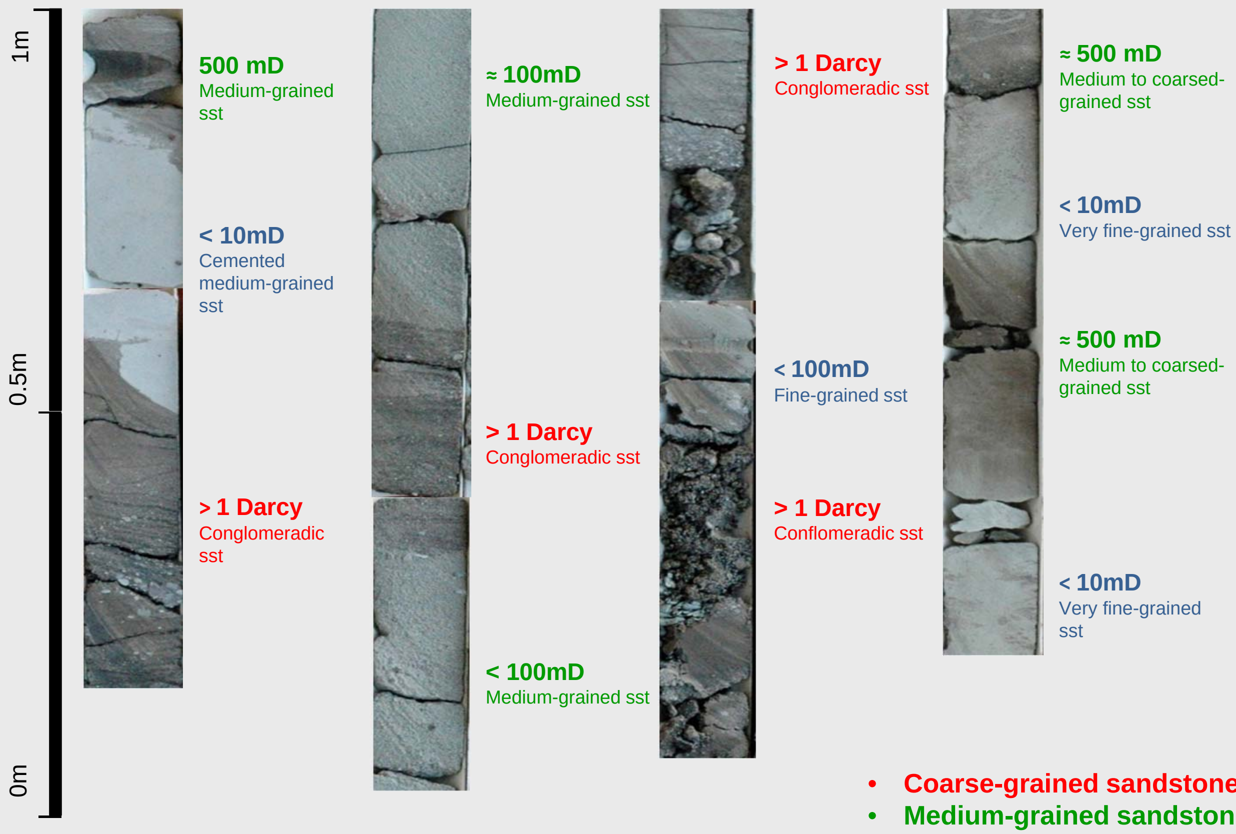
- Definition of 3 sandstone qualities inside channel belts (VCL – PHIE cutoffs)





- Permeability distribution based on porosity, for each type of sandstone

WATER SATURATION – STOIIP CALCULATIONS



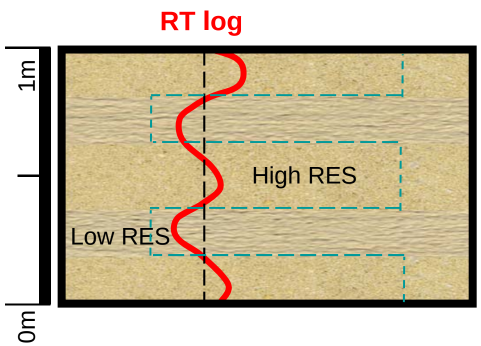
Interbedded sandstone-claystone

- Coarse-grained sandstones
- Medium-grained sandstones
- Fine-grained sandstones

WATER SATURATION – STOIIP CALCULATIONS

Resistivity response

Different sandstone qualities



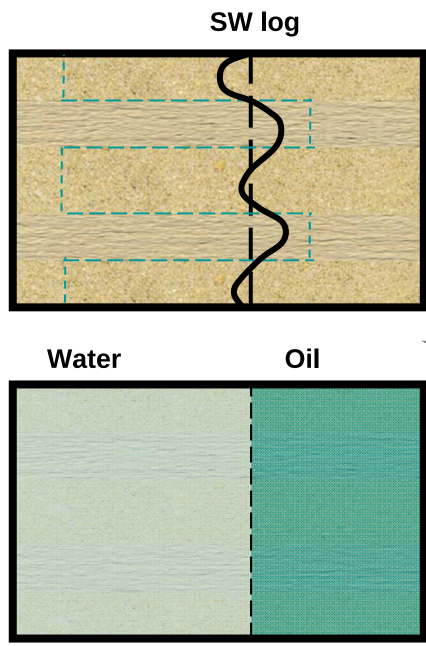
Low RES < RT log < High RES

But higher influence of lower values of RES

SW Interpolated from logs

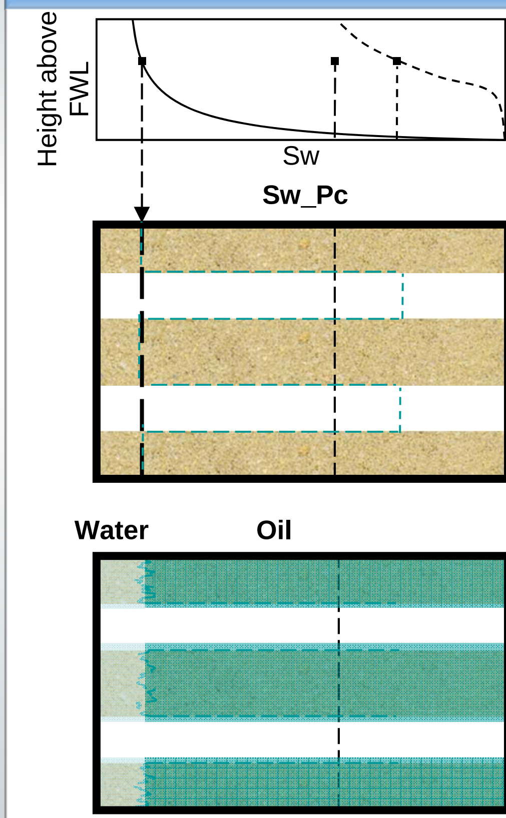
Conservative STOIIP calculations

- Different sandstone qualities



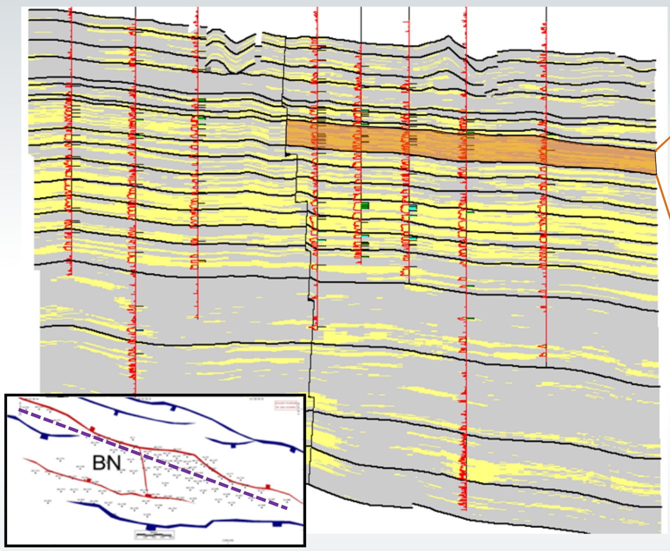
Lower STOIIP

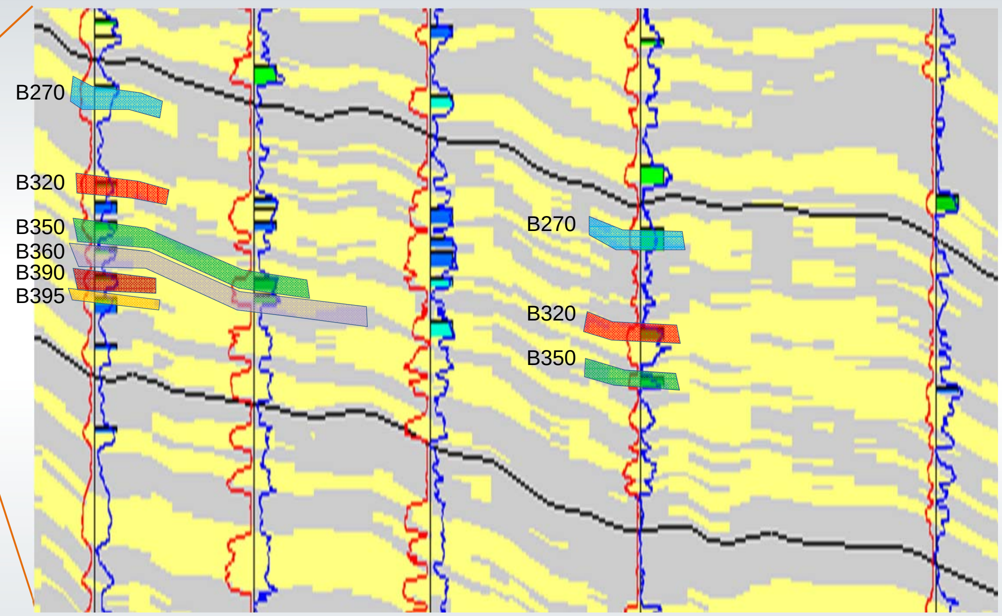
SW based on Pc curves



Higher STOIIP

STATIC MODEL – IMPACT ON STOIIP



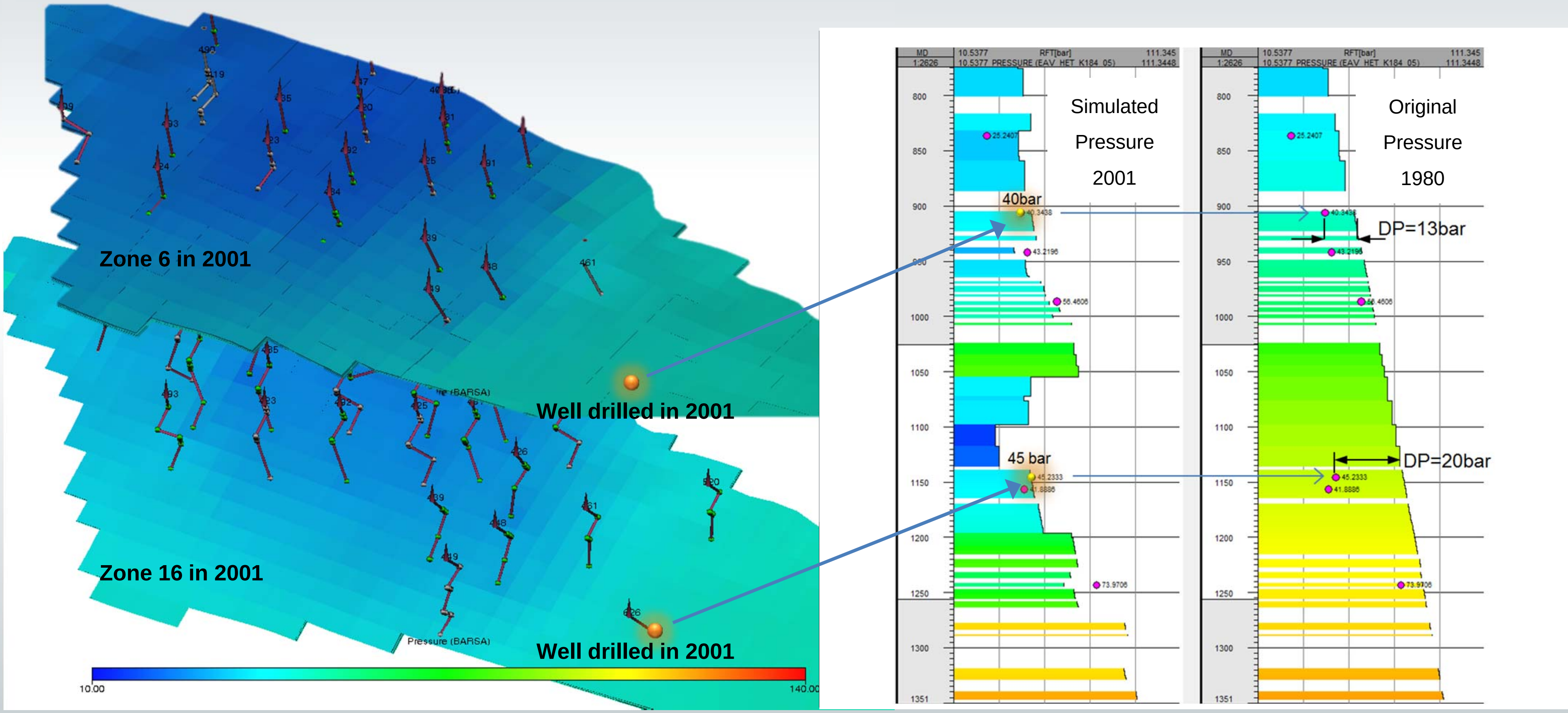


• STANDARD METHODOLOGY (isolated bodies, in colors, considering only wells that tested oil) → highly conservative STOIIP calculations

• CURRENT APPROACH (channel belts, yellow-grey background) → high vertical and lateral connectivity. More than tripled STOIIP

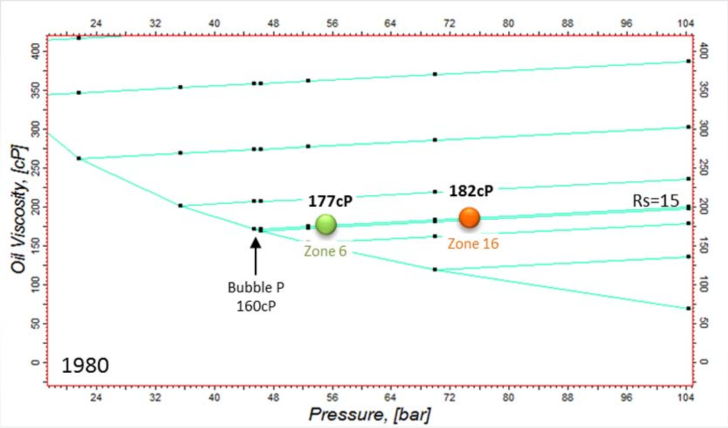
DYNAMIC SIMULATION – PRESSURE MATCHING

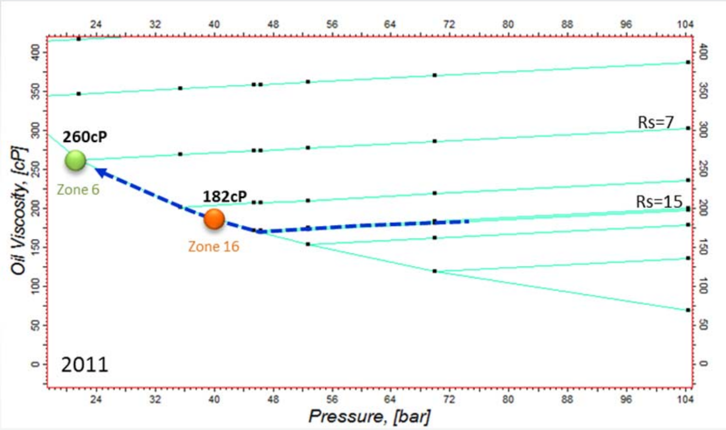
✓ Validation of hypothesis of continuity/connectivity of sandstones

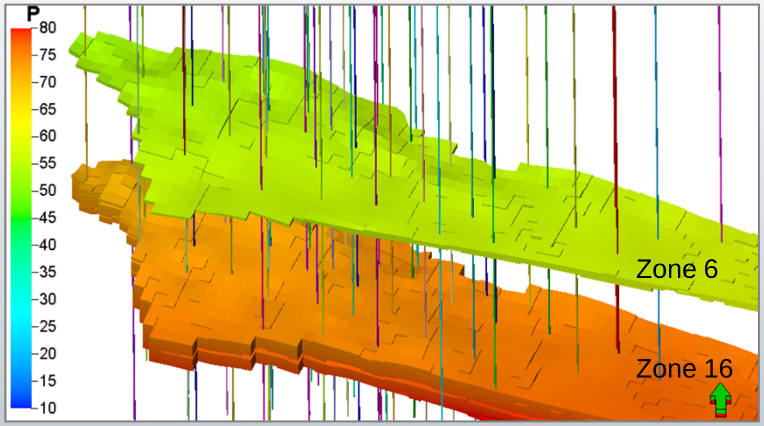


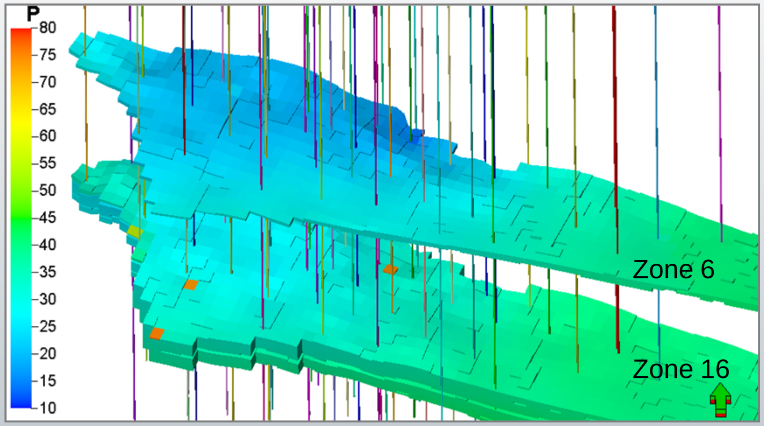
DYNAMIC SIMULATION – PRESSURE MATCHING

✓ High risk of increasing viscosity while depleting the reservoir



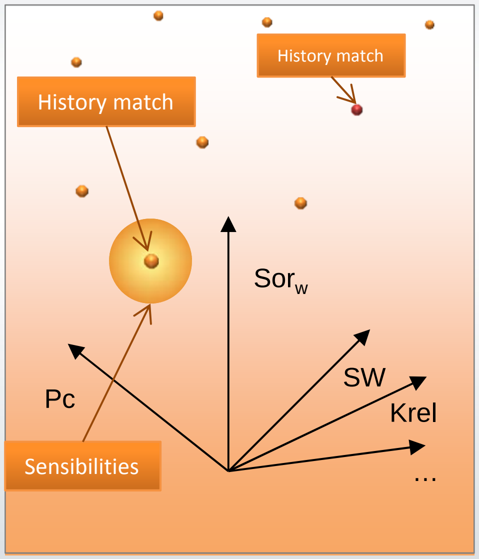


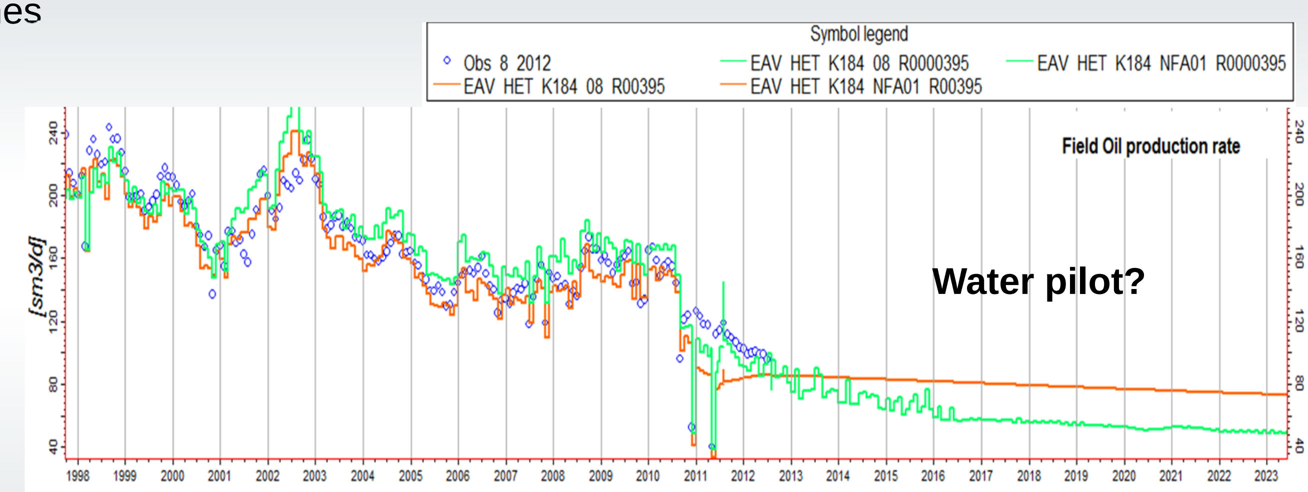




DYNAMIC SIMULATION – UNCERTAINTIES

- Parameters with high uncertainty: Pc, SW, SWirr, Sor, Krel
- Several possible primary matches





No clear secondary response ➜ **Insufficient injected volume (based on conservative STOIIP)**

Way forward: New water-pilot focused on the 2 better zones

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CONCLUSIONS

- **Standard methodology inconsistent with material-balance calculations**
- **Previous water-pilot inconclusive probably due to underestimated STOIIP**
- **Geological hypothesis validated by integrated 3D static-dynamic modeling**
- **Current approach allows identify of 2 zones with better chances for IOR**

Thank You

Acknowledgements: Elena Morettini & José L. Massaferro