3-D Static and Dynamic Modeling of a Carbonate Reservoir: Case Study from the Lower Cretaceous La Tosca Unit (Neuquén Basin, Argentina)*

Elena Morettini[1], Leticia Rodriguez-Blanco[2], Guillermina Sagasti[2], Anthony R. Thompson[2], Marta Valenzuela[2], and Jose Luis Massaferro[2]

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[1]YPF, Buenos Aires, Argentina (emorettini@ypf.com)
[2]YPF, Buenos Aires, Argentina

Abstract

The Lower Cretaceous Huitrín Formation of the Neuquén Basin (Argentina) consists of mixed clastic-carbonate-evaporite sediments of shallow marine to continental settings. The unit is subdivided into three lithostratigraphic members Chorreado, Troncoso, and La Tosca, all of which are hydrocarbon bearing in varying locations of the basin. This work presents the integrated 3D static and dynamic reservoir characterization and modeling of the La Tosca unit. The main structure in the area is an East-verging basement anticline with ElPichanal, PataMora, and PuestoMolina fields all being located on its western flank. Both a High Resolution Sequence Stratigraphic model and a Discrete Fracture Network model, were built through the integration of seismic, core, well cuttings, borehole imaging and log data, and validated by well tests and dynamic simulations. La Tosca depositional sequence consists of a third order transgressive-regressive 30 m-thick cycle accumulated on a shallow carbonate platform. Main deposits comprise low- to high-energy subtidal to intertidal facies including skeletal banks, ooid-skeletal shoals, peloidal platform interior, algal mats, and sabkha deposits. The facies stacking pattern allows further subdivision of the unit into possible fourth and fifth order accommodation cycles. Fourth order cycles show evident facies partitioning, with overall argillaceous-carbonates dominating transgressive hemicycles and clean carbonates (ranging from skeletal and oolitic grainstones to algal-mat boundstones) dominating regressive hemicycles. Fifth order cycles also show similar facies partitioning, with transgressive hemicycles bearing argillaceous limestones and regressive cycles characterized by oomoldic and skeletal grainstones. Two types of fractures, diagenetic and tectonic, were identified, with diagenetic fractures showing preferential occurrence within the regressive portions of the 5th order cycles mainly in oomoldic grainstones due to enhanced cementation and in algal mats due to desiccation. Tectonic fractures are ubiquitous and their intensity is related to fault distance. We propose a model of dual porosity where matrix acts as hydrocarbon storage and fractures provide production mechanism. The best

matrix reservoir intervals occur within 5th order regressive hemicycles where permeability of oomoldic and algal mat facies is enhanced by a network of centimeter-scale diagenetic fractures.

Selected Reference

Schwarz, E., L.A. Spalletti, and J.A. Howell, 2006, Sedimentary response to a tectonically induced sea-level fall in a shallow back-arc basin; the Mulichino Formation (Lower Cretaceous), Neuquen Basin, Argentina: Sedimentology, v. 53/1, p. 55-81.

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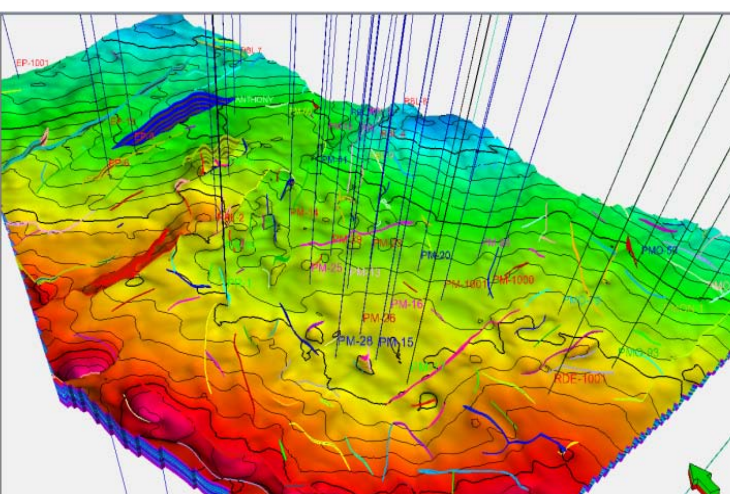
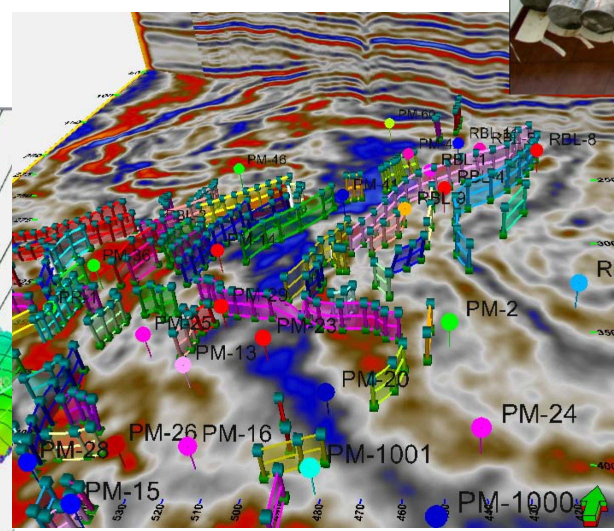
YPF - Dirección E&P - Geociencias - Desarrollo de Yacimientos - *UNAO





AAPG 2012 ANNUAL CONVENTION & EXHIBITION

Outline of the presentation

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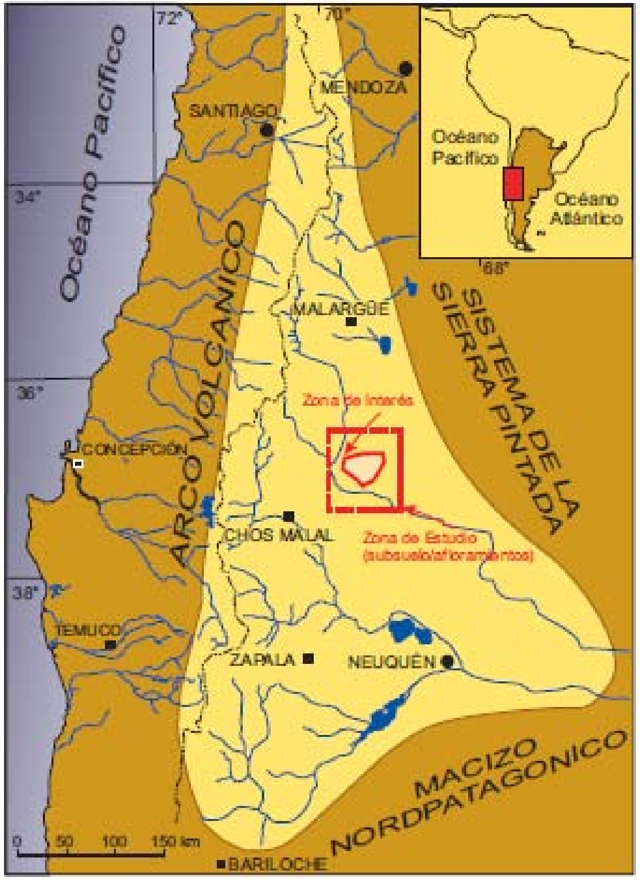
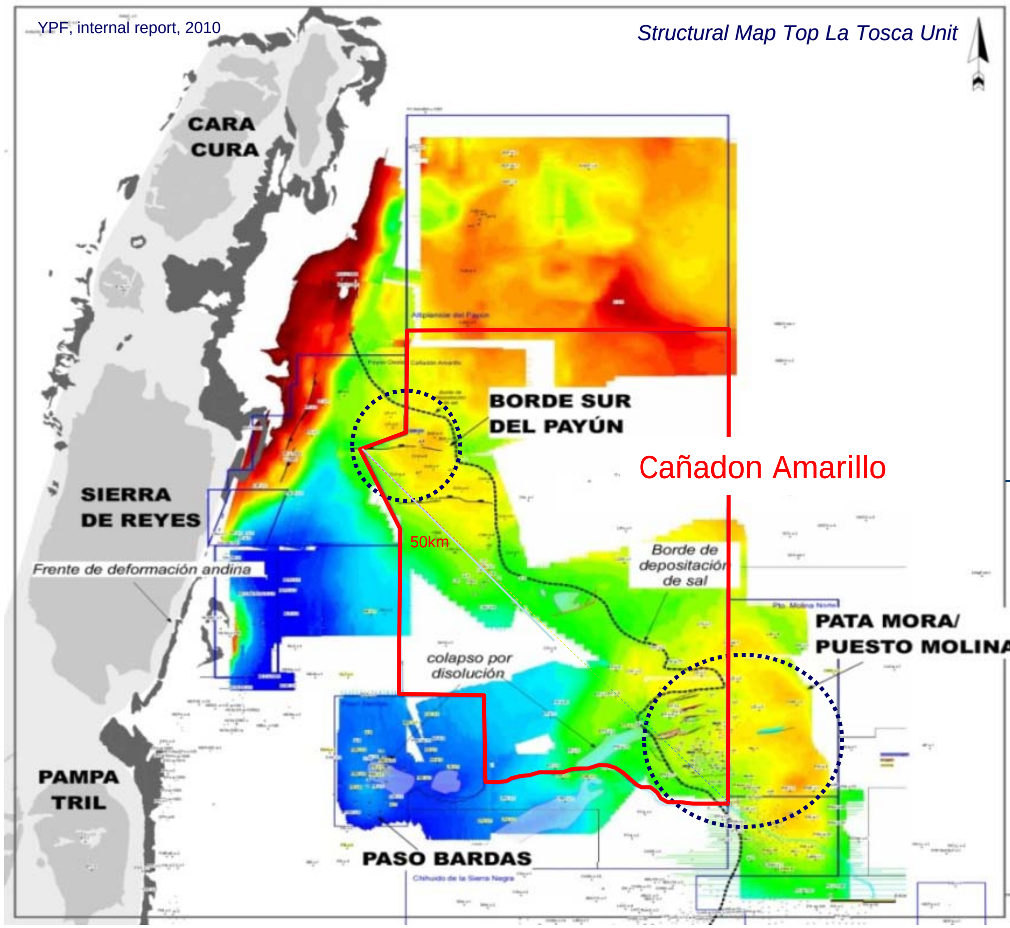
- Objective and area of study
- Methodology for multidisciplinary reservoir characterization
- Overview of the Neuquén Basin
- Structural characterization of the study area
- Core scale: fractures, facies and sedimentary cycles
- High Resolution Sequence Stratigraphy correlation
- Fracture and depositional models
- 3D reservoir model in *Petrel*
- Dynamic model
- Conclusions

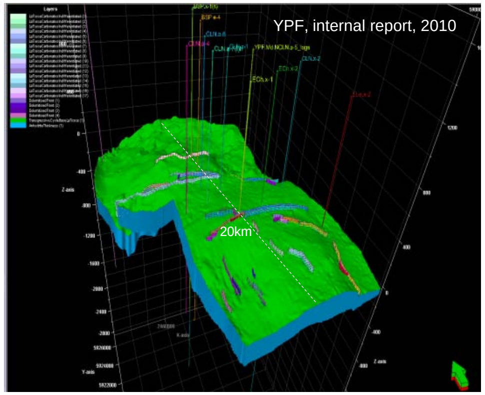


Courtesy of Schwarz, E. et al. (CIG-La Plata)

Objective

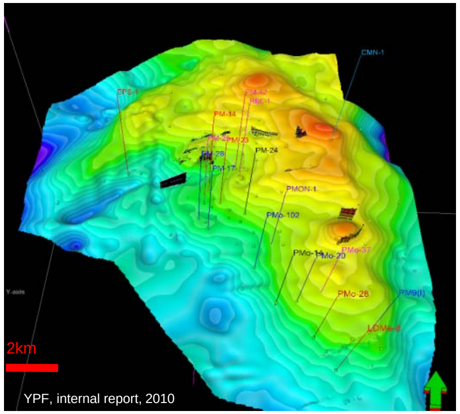
Build predictive 3D static and dynamic model of La Tosca Unit (Huitrín Formation) to characterize reservoir, production mechanisms and exploratory play in the block of Cañadon Amarillo





Borde Sur Payún Area
4 wells
Depositional Setting
Arid Carbonate Ramp
Structural Setting
Salt-tectonic - Intrusive Related Anticline
Reservoir
La Tosca Unit c.a 30m

Uncertainties
- Hydrocarbon Play
- Production mechanism
- Next Well
- Relationship with Pata Mora



Pata Mora Field
~ 40 wells
Depositional Setting
Carbonate Ramp
Structural Setting
Basement Anticline
Reservoir
La Tosca Unit c.a. 25-30m

Uncertainties
- Hydrocarbon Play
- Production mechanism
- Next Well
- Relationship with BSP

Methodology
for Multidisciplinary Reservoir Characterization

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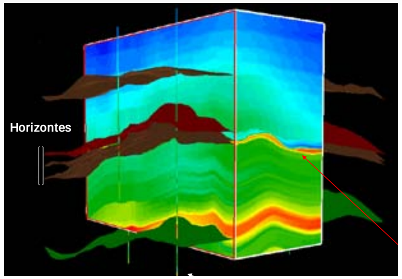
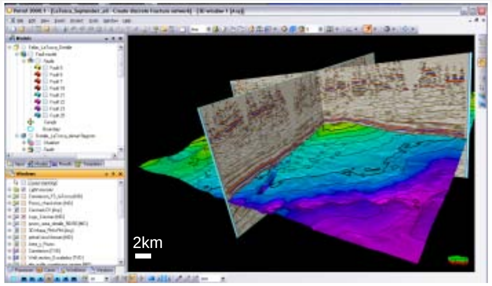
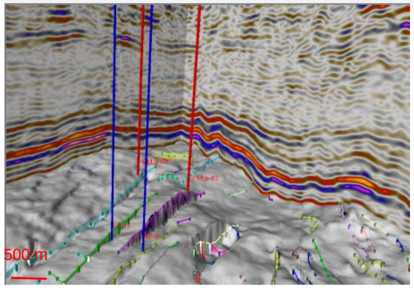
Seismic

- Volume seismic interpretation
- Depth Conversion
- Geometries and Seismic Facies Mapping
- Integration with regional 3D and 2D lines
- Attribute Calculation
- Quantitative interpretation

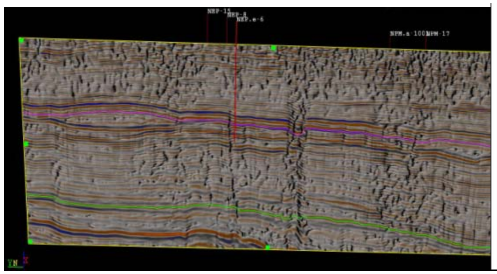






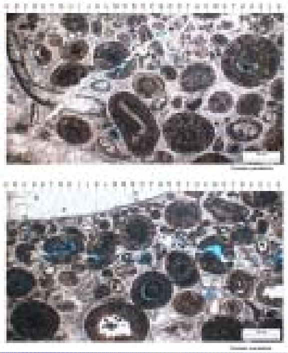
Structural geology

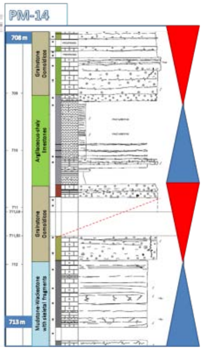
- Seismic Fault characterization
- Core-based fracture characterization
- Fracture-dynamic data calibration
- Discrete fracture modeling (DFN)
- Building of predictive fracture model

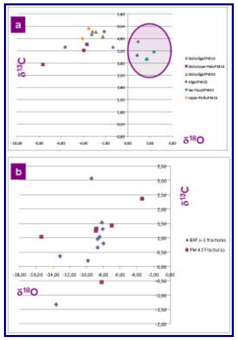


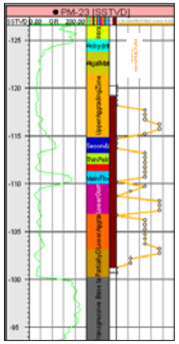
Sedimentology & HRSS

- Facies description
- Sedimentary cycles interpretation,
- Core-to-log calibration,
- HRSS correlation framework
- Spatial distribution of facies
- Diagenetic model
- Mechanical Stratigraphy



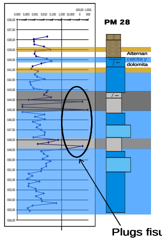


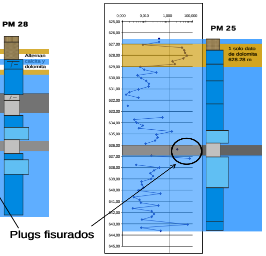


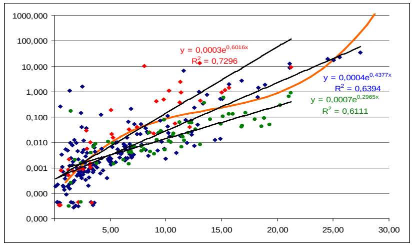


Petrophysics

- Petrophysical core-data analysis and correlation
- Porosity and permeability correlation
- Facies for K relation







Neuquén Basin
Structural Development and Stratigraphy

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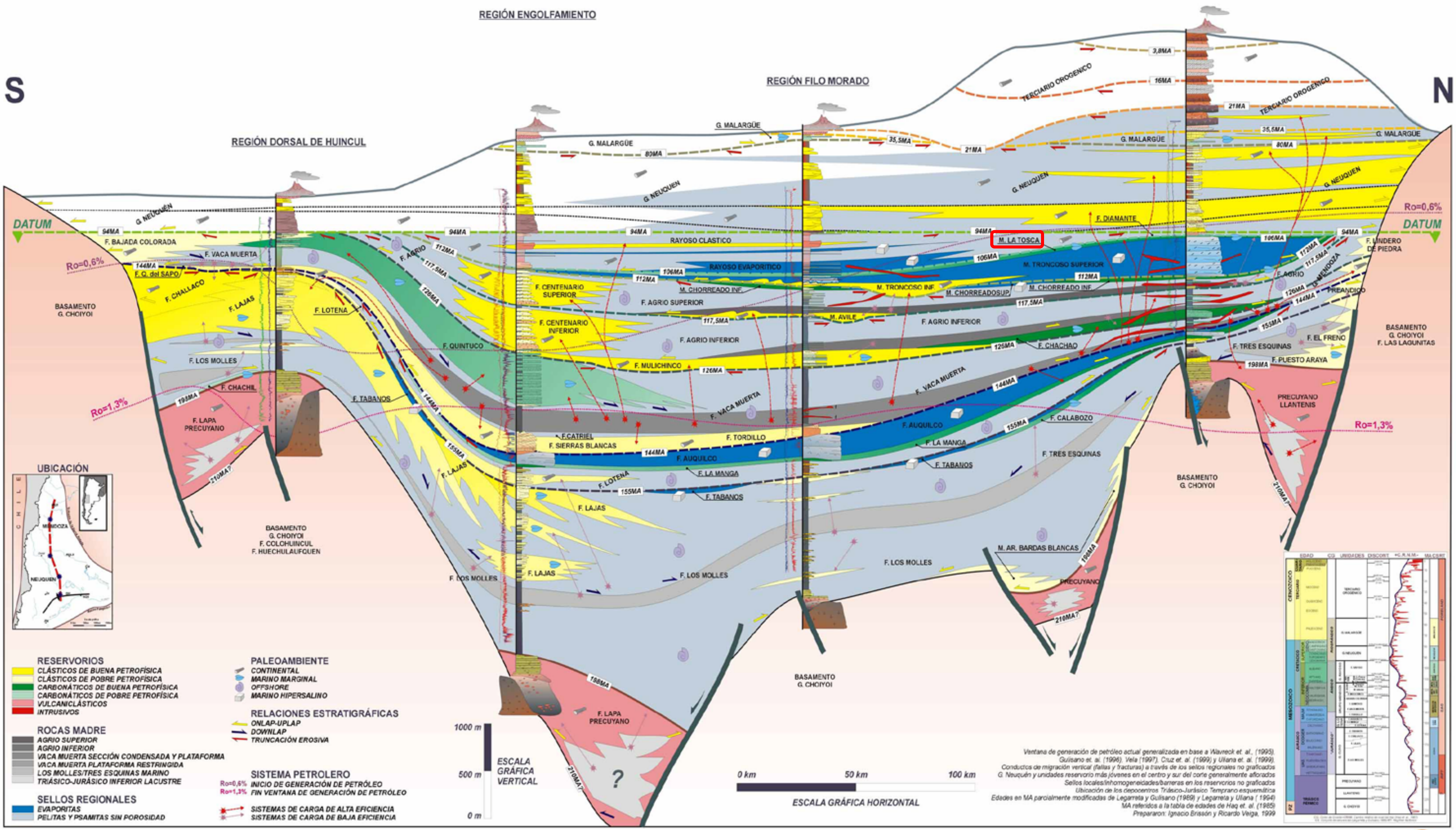
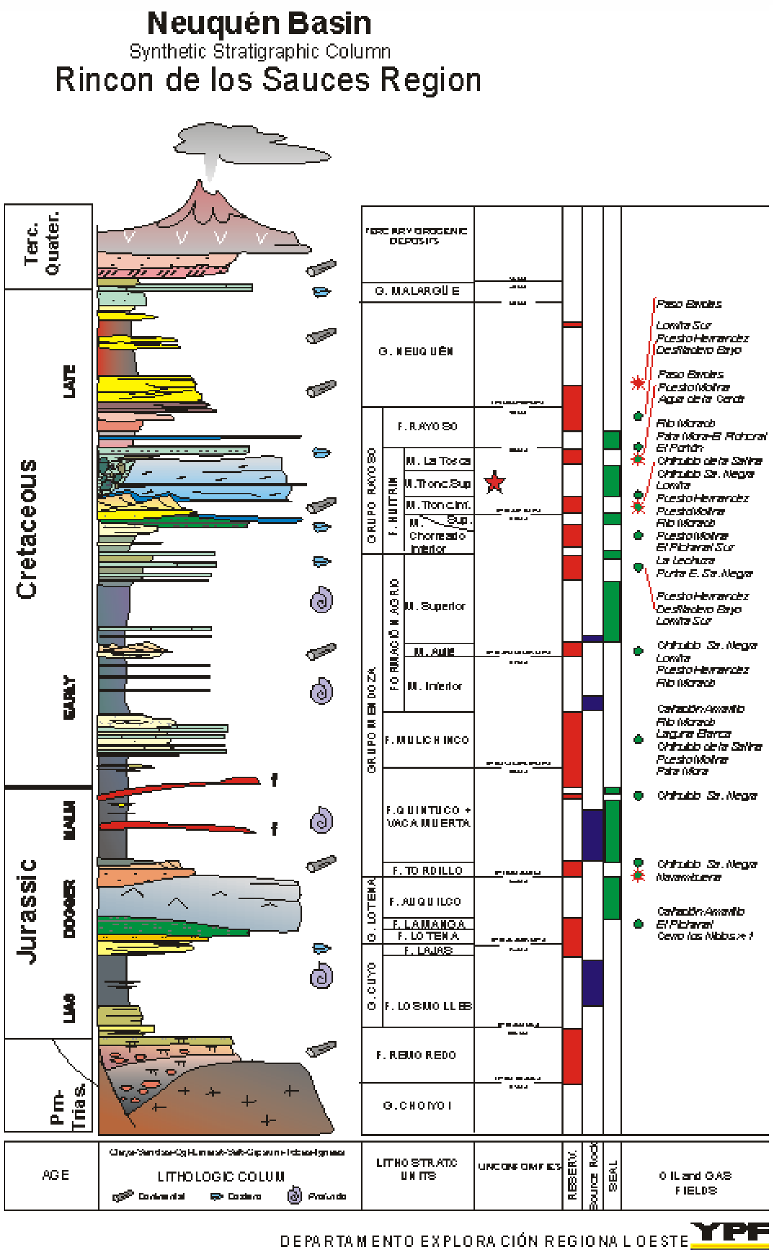
Simplified N-S Stratigraphic Section of the Central-Western portion of the Neuquen basin
DATUM: INTERSENONIAN UNCONFORMITY



Neuquén Basin
Structural Development and Stratigraphy

YPF

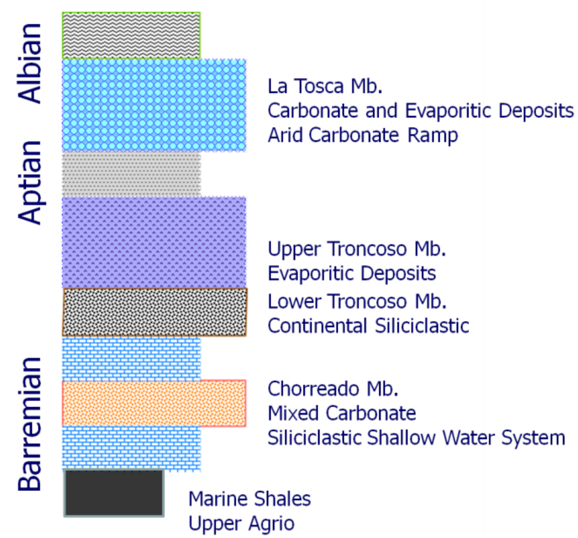


Lower Cretaceous

- Magmatic arc development
- Back-arc Basin
- Sedimentary cover controlled by interplay of subsidence, local uplifts and sea-level oscillation during thermal subsidence

Huitrín formation

- Barremian-Albian
- 3 lithostratigraphic members: Chorreado, Troncoso and **La Tosca**
- Mixed clastic-carbonate-evaporite sediments
- Shallow marine to continental settings
- HC bearing.



Study Area
Structural Setting

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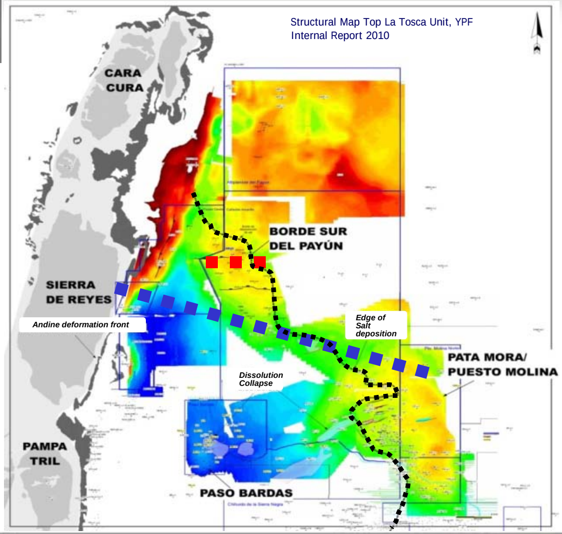
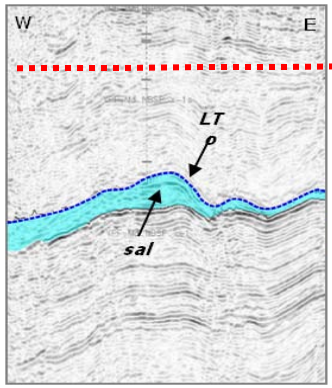
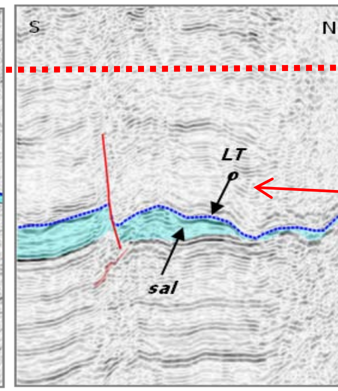


Differentiated Structural Settings





Foreland

Internal sector

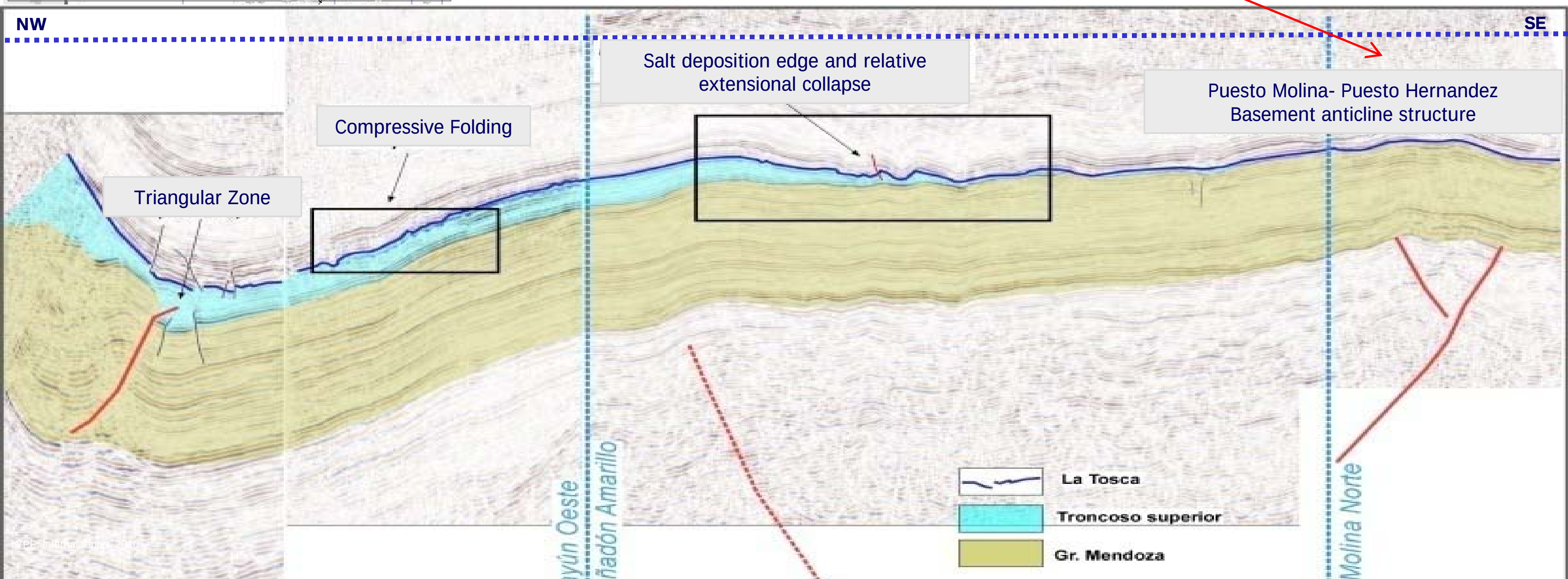
salt-tectonic structures superimposed over basement-controlled ones

Borde Sur del Payún

External sector

basement-controlled structure

Pata Mora



Field Scale
Seismic Fault Interpretation

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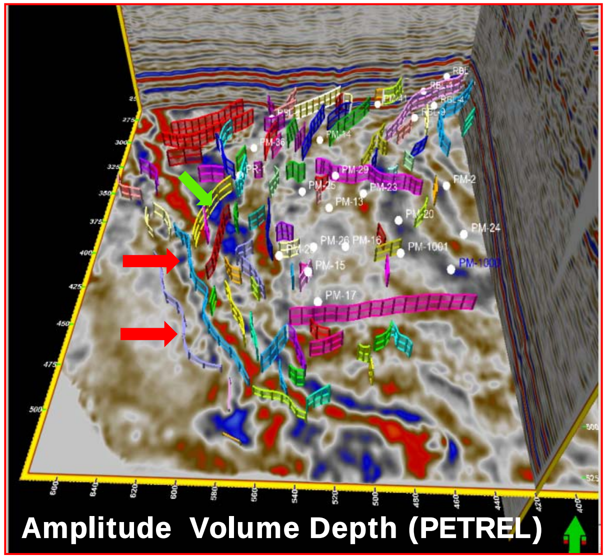
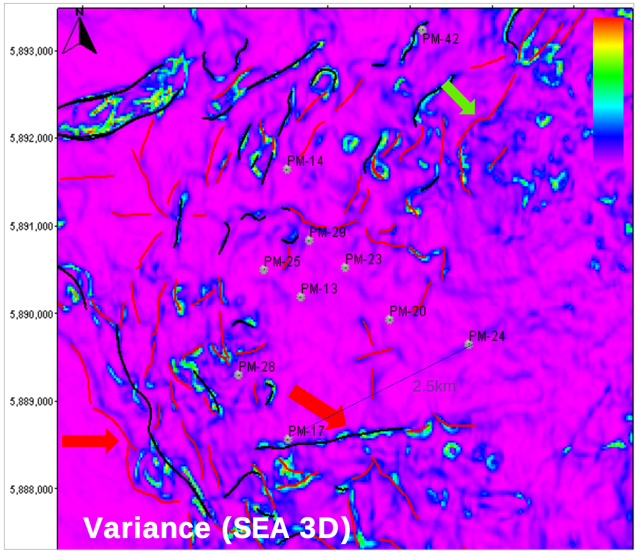
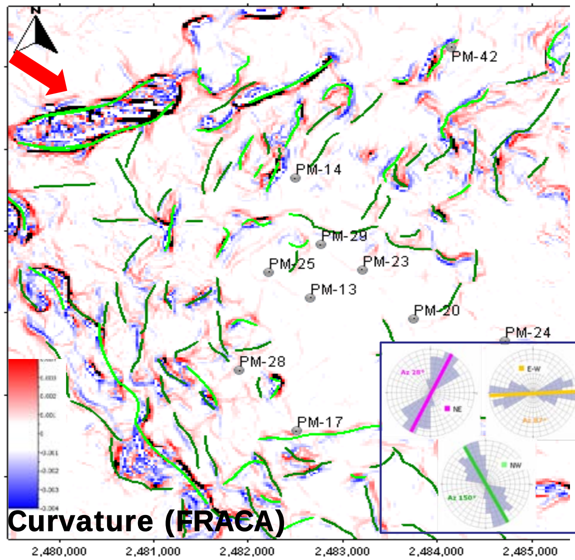
Detailed interpretation of faults and lineaments from seismic amplitude and attributes

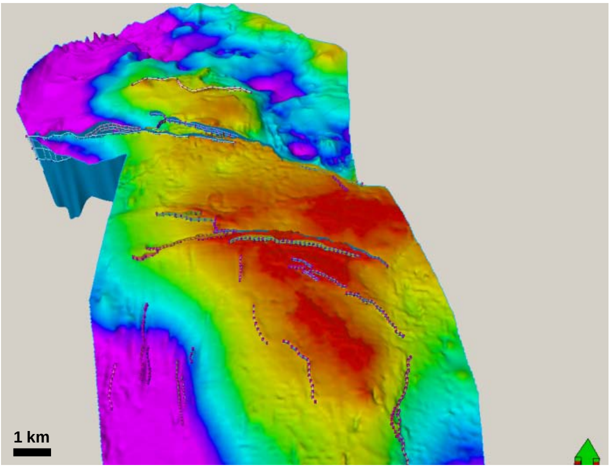
Principal Faults **E–NE y N-NW** Major throw and displacement

Secondary Faults **NE-SW** Minor throw and displacement

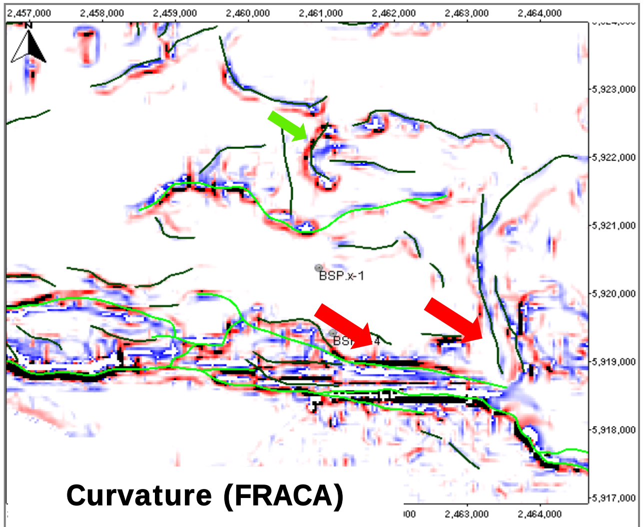


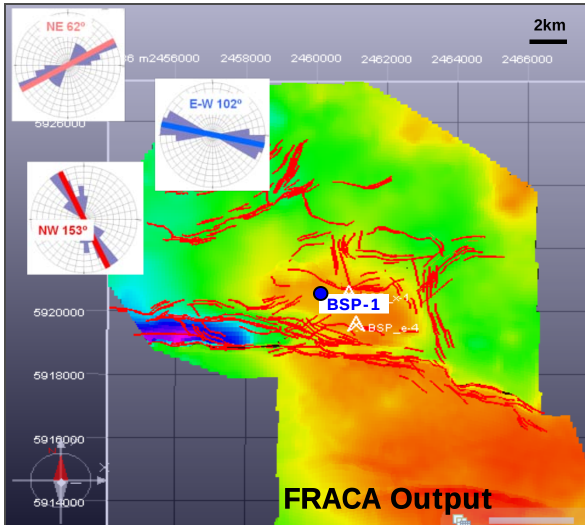






Seismic Horizon Depth (PETREL)





Field Scale

Fracture Characterization in Cores (PM-14 PM-17 PM-23 PM-24 PM-25 PM-28 PM-42 BSPx1)

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MACROFRACTURES

- Fracture density / 0.5m
- Cementation degree
- Longitude
- Aperture
- Inclination
- End-points

$$\text{FRACTURE INDEX} = \frac{\text{cumulative fracture length} * 0.01}{\text{total core length}}$$

MICROFRACTURES

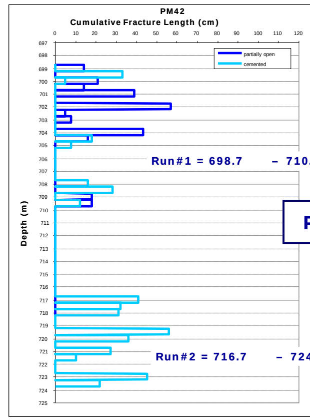
- presence/abundance

$$\text{MICROFRACTURE INDEX} = \frac{0.5 * \text{n°recorded mF}}{\text{total core length}}$$

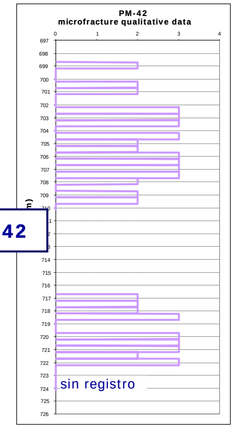
Fracture Intensity

Cumulative Length vs Depth

MF

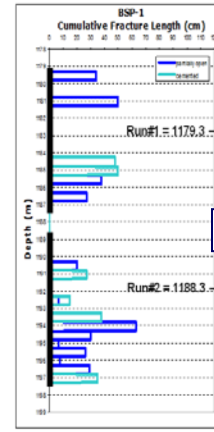


mF

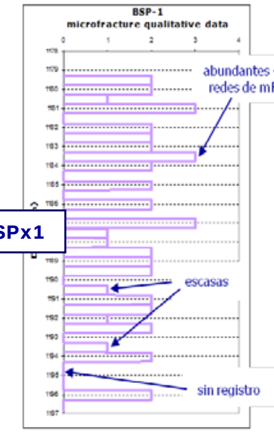


PM42

MF

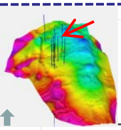


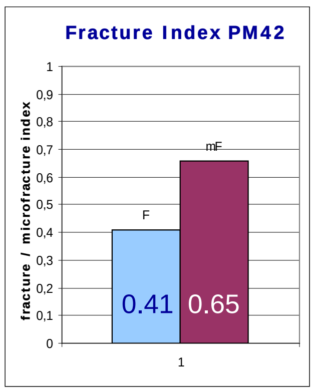
mF

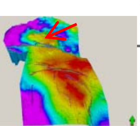


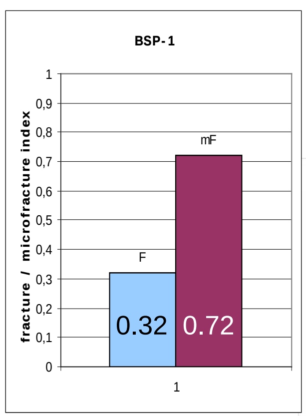
BSPx1

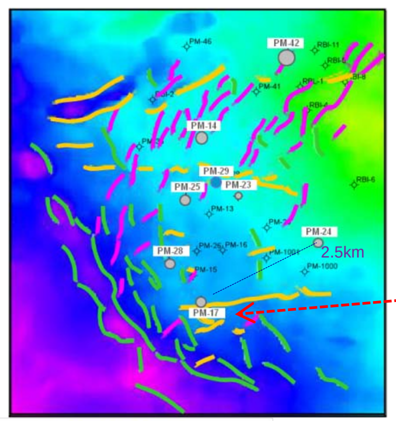
FI is directly related to fault-proximity

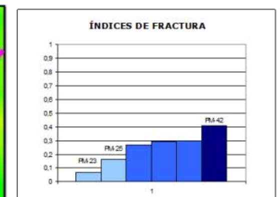




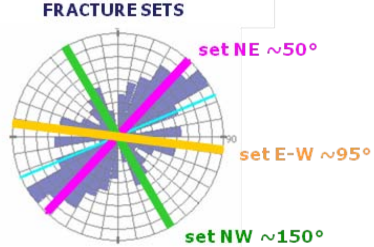


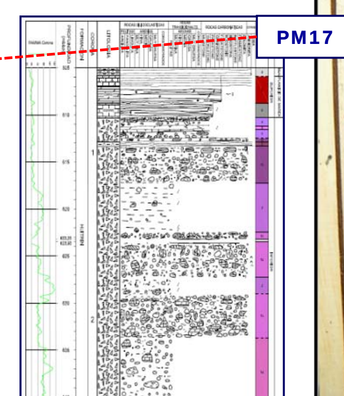






FRACTURE SETS





Field Scale

Facies Definition in Cores (PM-14 PM-17 PM-23 PM-24 PM-25 PM-28 PM-42 PM-1001 BSPx1)

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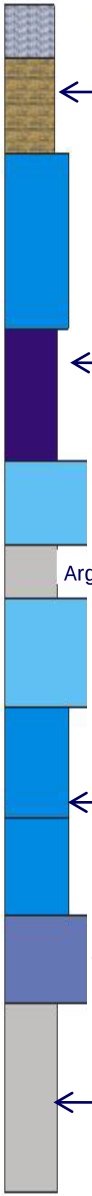
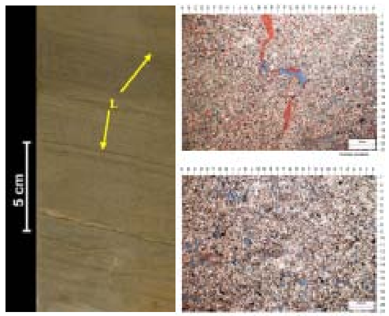
Main deposits comprise low- to high-energy subtidal to intertidal facies including skeletal banks, ooid-skeletal shoals, peloidal platform interior, algal mats and sabkha deposits

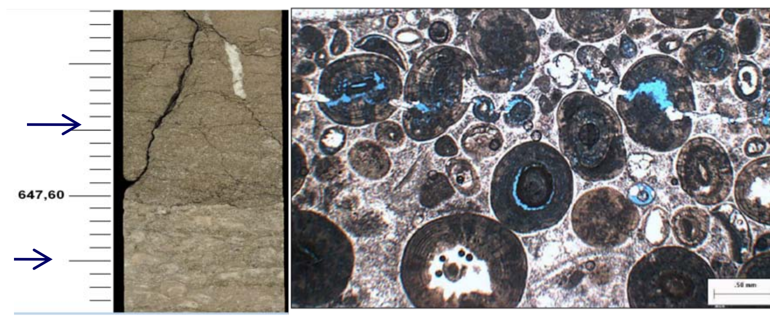


Algal Mats
PM 14

Argillaceous
Limestones
PM 23

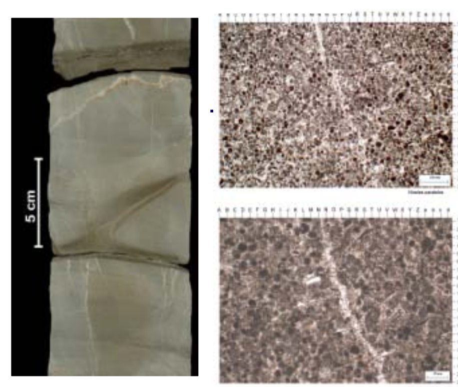


Oolitic Grainstone (oomoldic)
PM28

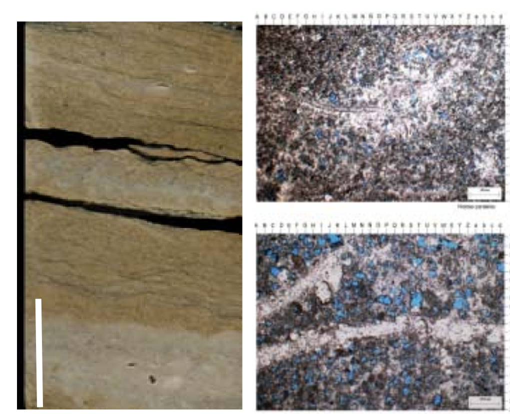


Argillaceous Limestones

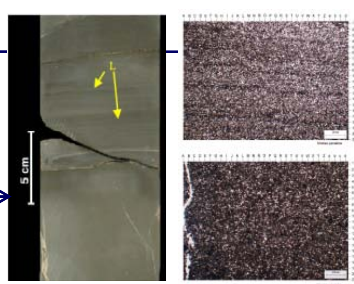
Oolitic Skeletal Grainstone
(oomoldic)
PM28



Fine-grained
peloidal grainstone
PM14



Skeletal packstones
PM 23



Claystones-Marls
PM 23

Field Scale
High Resolution Sequence Stratigraphy in Cores

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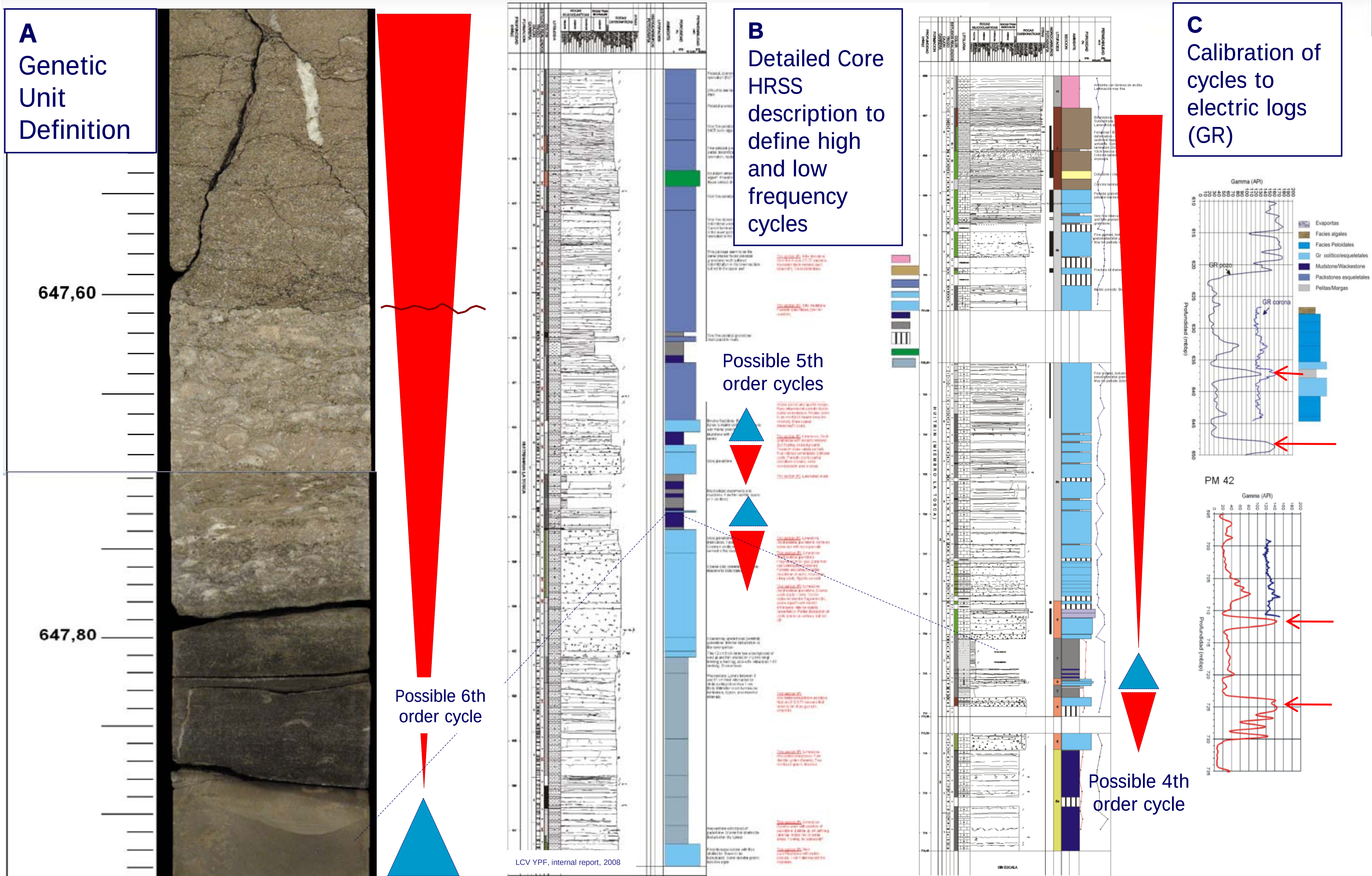
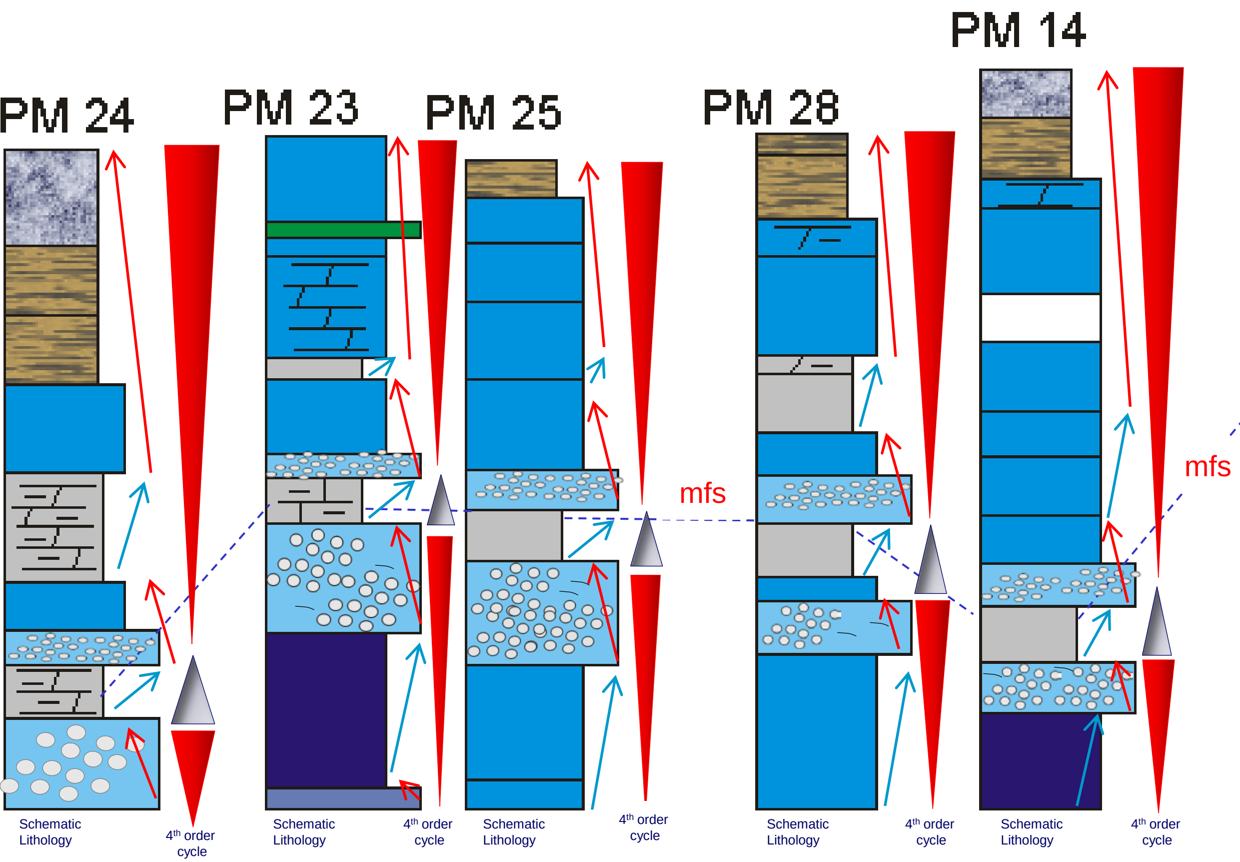
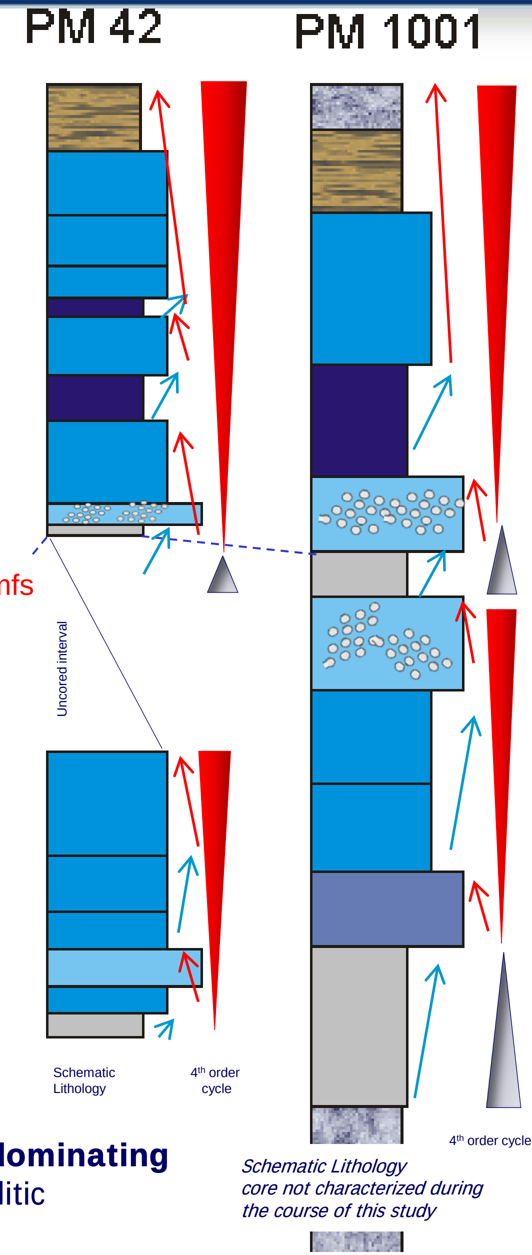
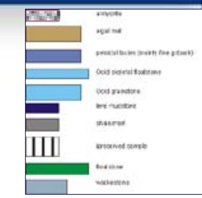


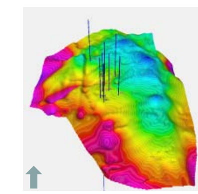
High Resolution Sequence Stratigraphic Correlation

La Tosca depositional sequence: **3rd order** transgressive-regressive 30 m-thick cycle accumulated on a shallow carbonate platform.









Facies stacking pattern: **2** probable **4th order** (14 to 19 m thick) and **4** probable **5th order** (3 to 13 m thick) accommodation cycles.

4th order cycles show facies partitioning, with overall **argillaceous-carbonates dominating transgressive hemicycles** and **clean carbonates** (ranging from skeletal and oolitic grainstones to algal-mat boundstones) **dominating regressive hemicycles.**

Depositional model Cañadon Amarillo (S-N)

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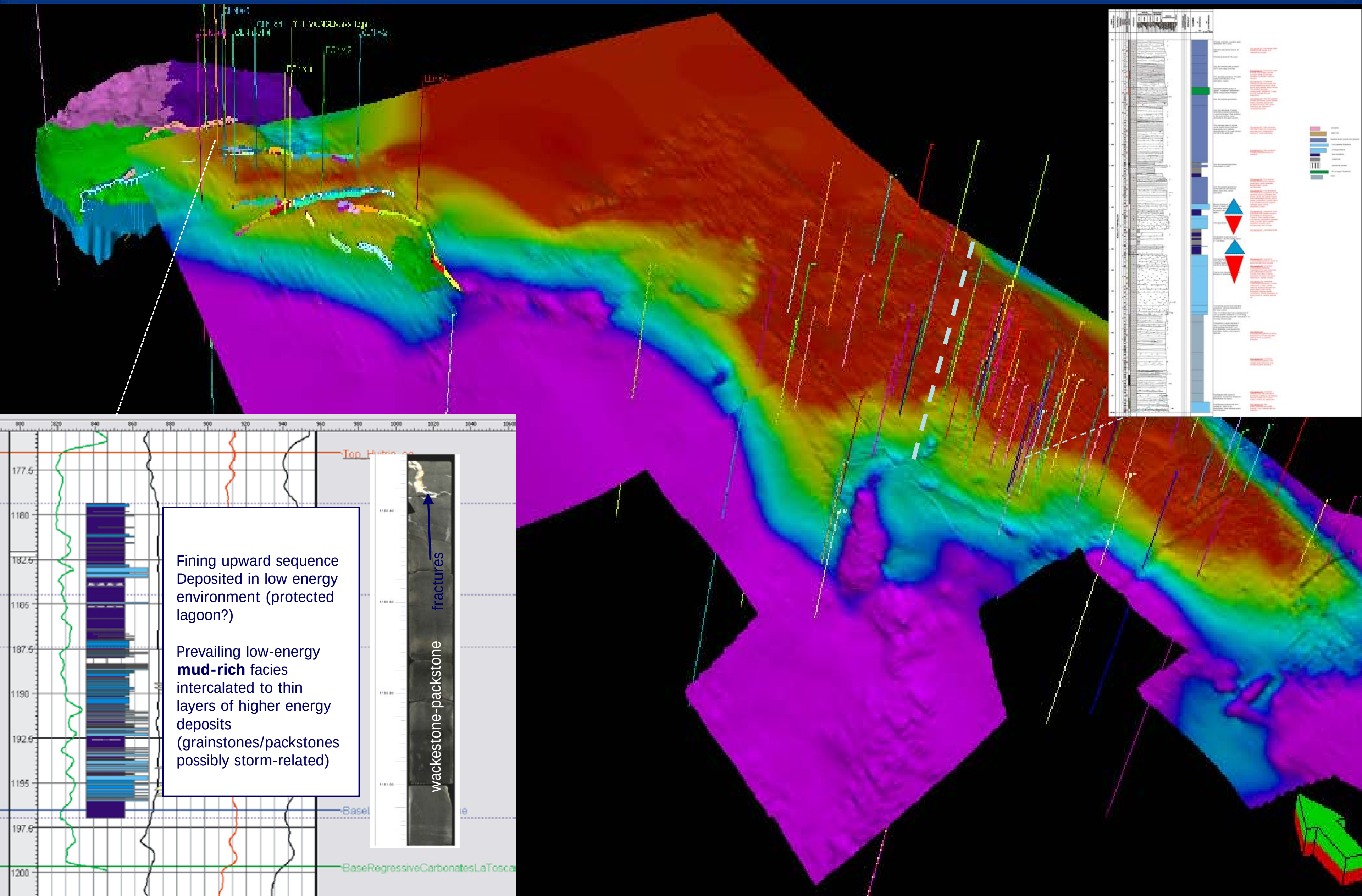
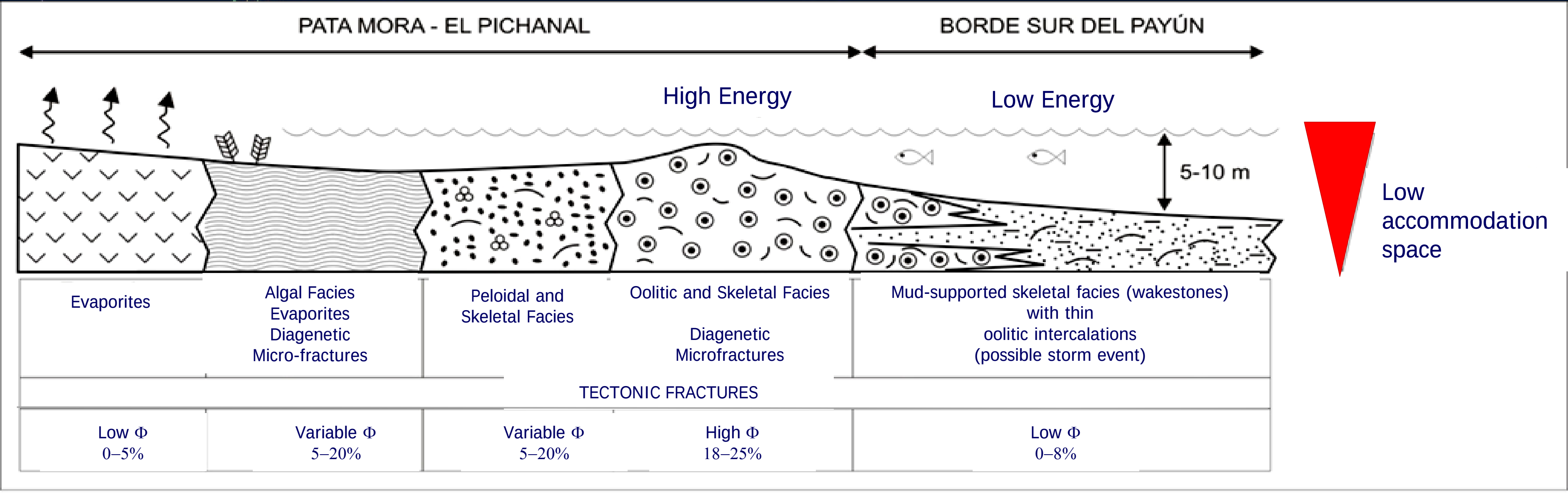
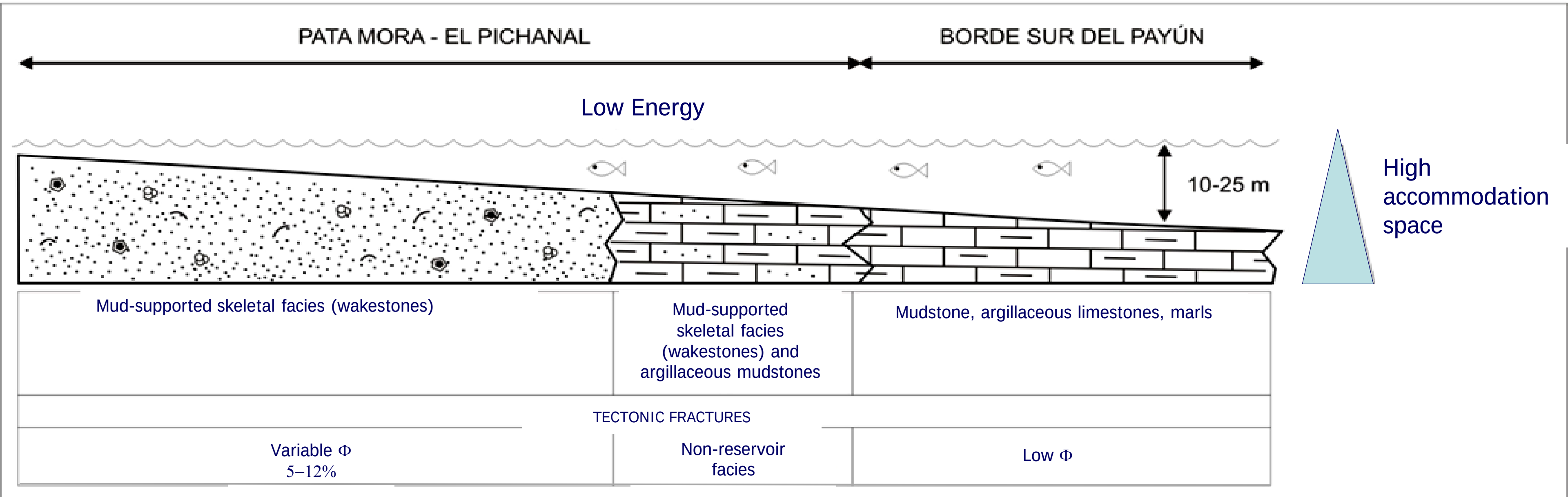


Depositional model Cañadon Amarillo (S-N)

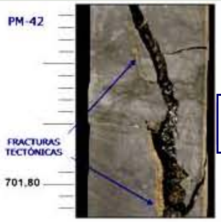




Conceptual
Fracture Conceptual Model

YPF

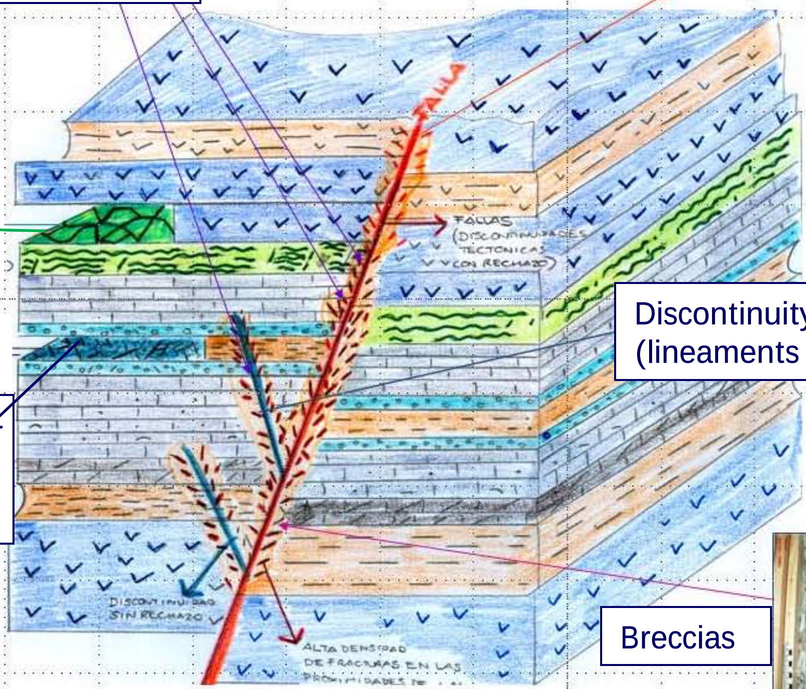
Fracture Conceptual Model (different scales)

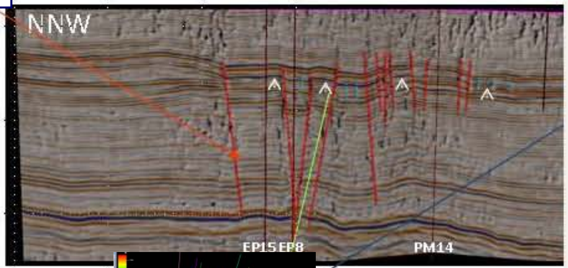


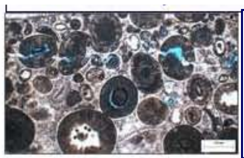
Tectonic Fractures

Faults with throw

Bed-bounded diagenetic micro-fractures (algal mats)

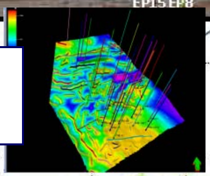




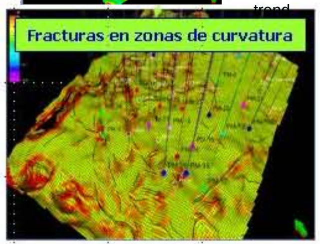


Bed-bounded tectonic micro-fractures (oomoldic grainstones)

Discontinuity Zones (lineaments or folds)

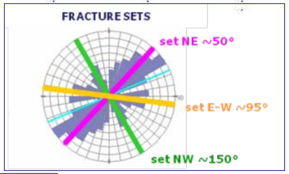


Permeability Enhancement combination of curvature and NE fault trend

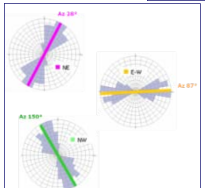


Breccias

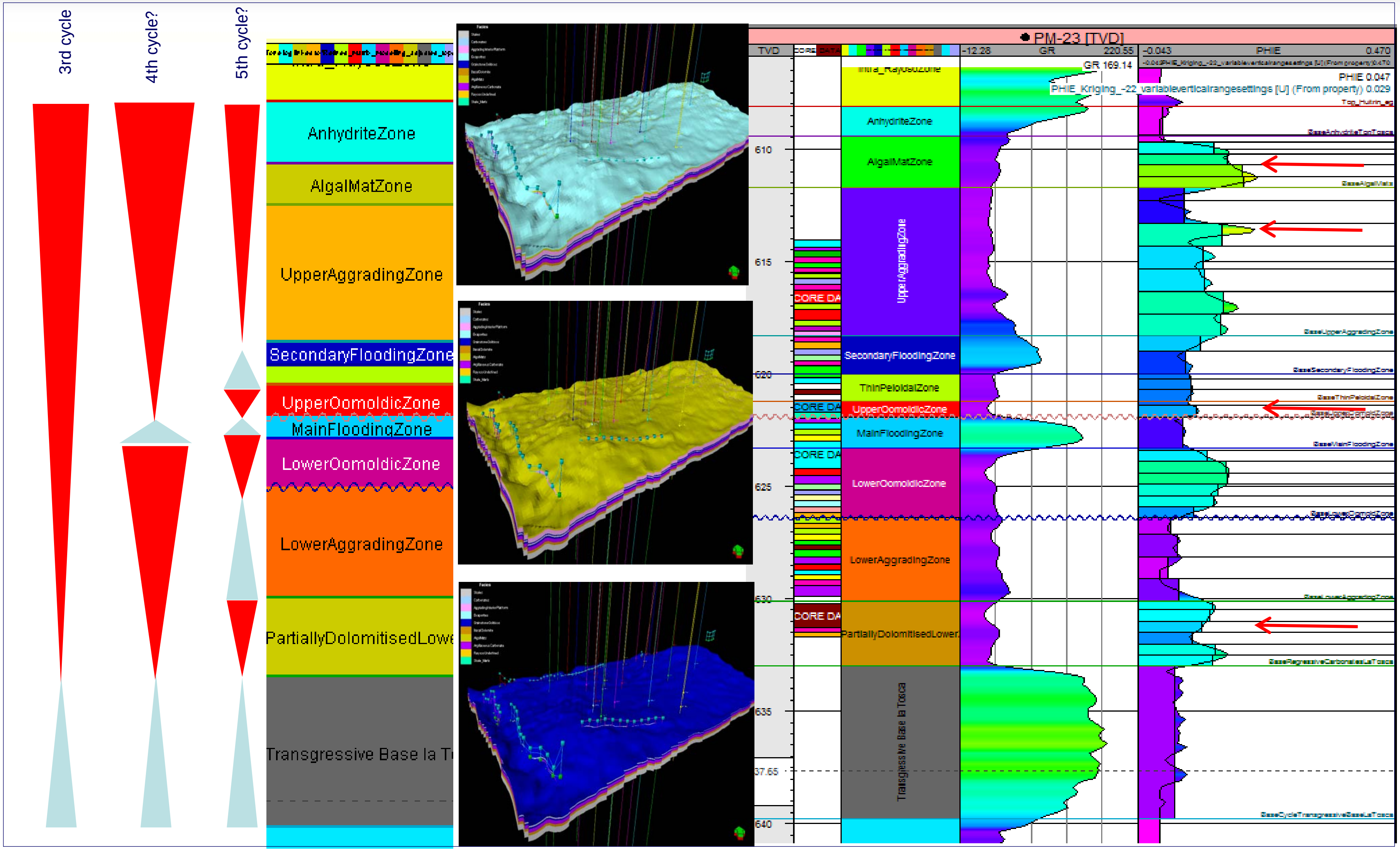
- Two types fractures
  diagenetic (micro-fractures) and **tectonic** (micro and macro-fractures)



- Two main fault families
  Principal Faults **E–NE y N-NW** Major throw and displacement
  Secondary Faults **NE-SW** Minor throw and displacement

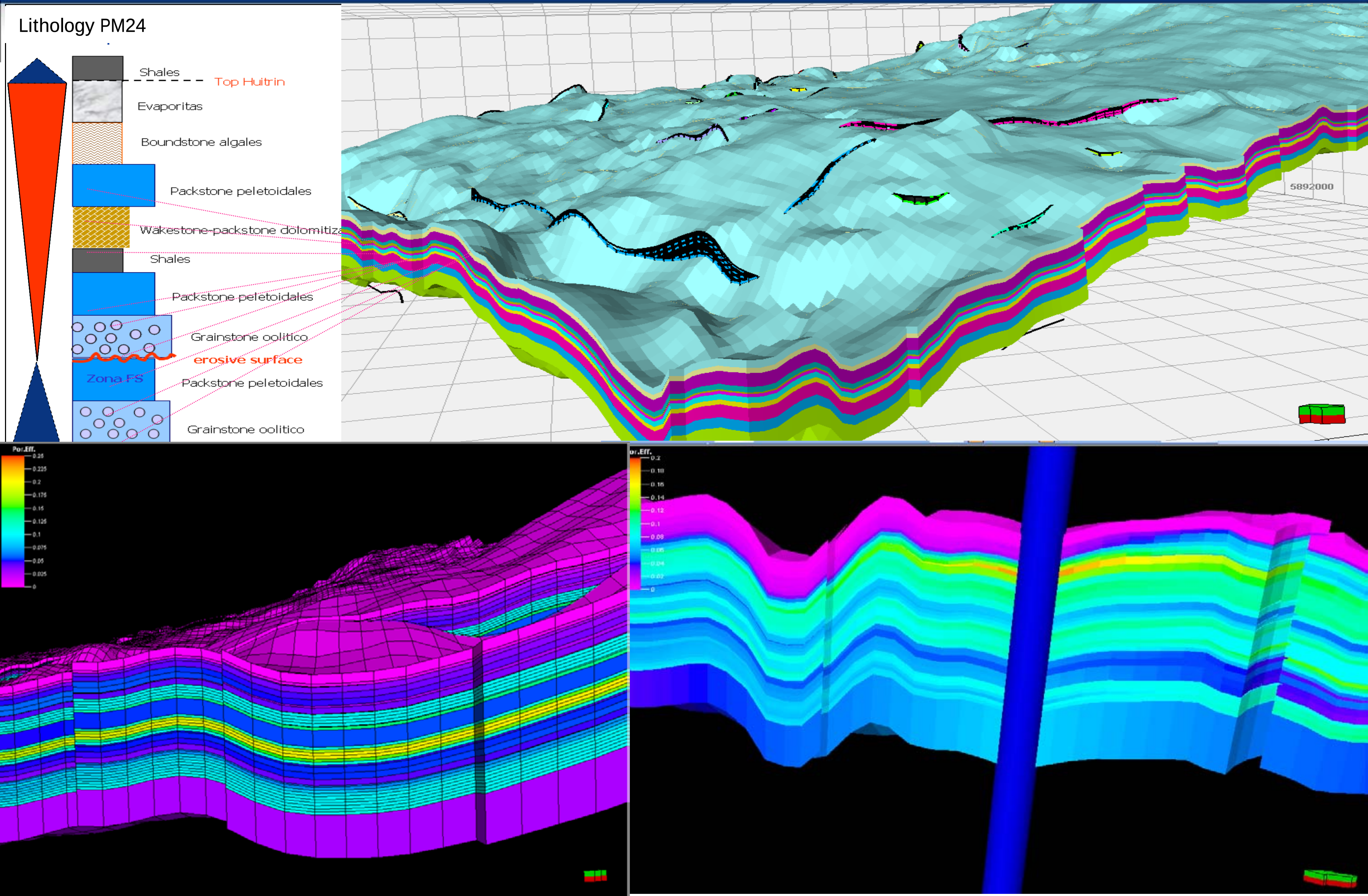


Core-based Reservoir Model (Petrel)



Core-based Reservoir Model (Petrel)

YPF



What was learned from dynamic simulation?

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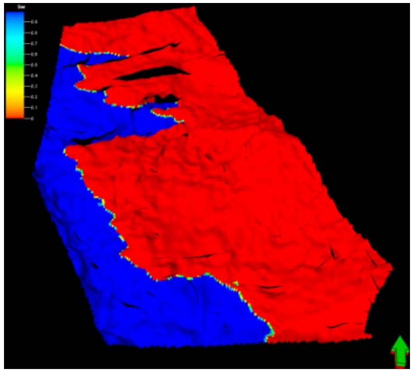
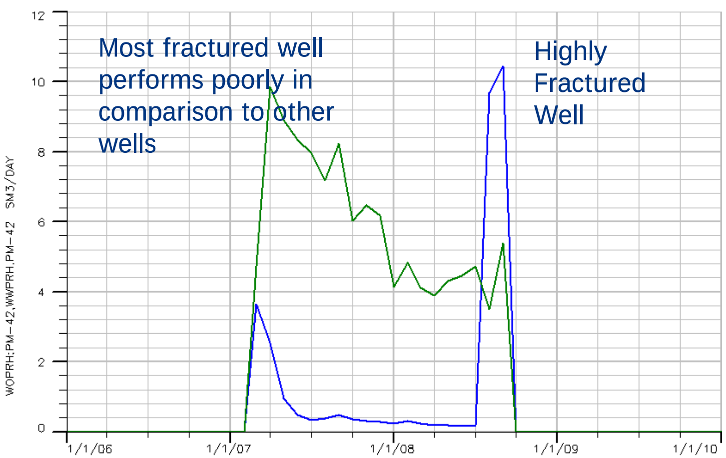
Fractures

- **Historical production rates only achievable with fractures**
- Oil contact in fractures shallower than in matrix
- Fracture volumes typical 0.2-0.5% of GRV
- OWC in the fracture system shallows moving from South to North
- Flow to wells is through fracture system

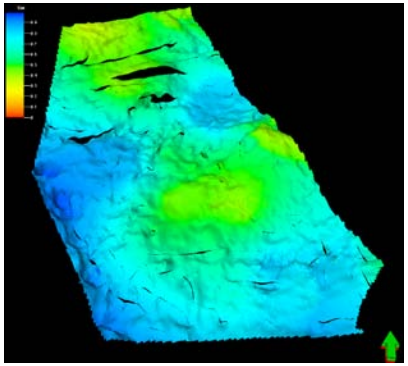


By history matching historical production, the regions to the deeper west were identified as being water bearing



Matrix

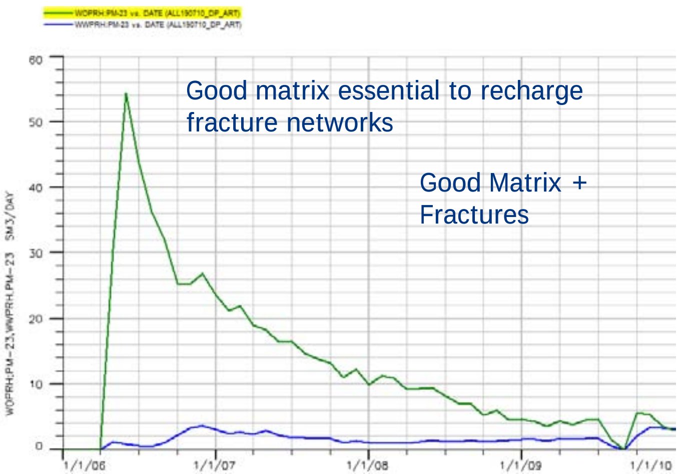
- **Good matrix essential to recharge fracture networks**
- Matrix is oil wet and basically un-depleted
- Low connectivity between matrix and fractures



Matrix Saturation in comparatively High Porosity layer. Oil bearing rock even on the deeper west of the model.

Oil contact in fractures shallower than in matrix.

For oil to be resident in the matrix deeper than the fracture system, oil must be preferentially attracted to the matrix, hence the rock must be oil wet.



Conclusions

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Build predictive 3D static and dynamic model of La Tosca Unit (Huitrín Formation) to characterize reservoir, production mechanisms and exploratory play in the block of Cañadon Amarillo

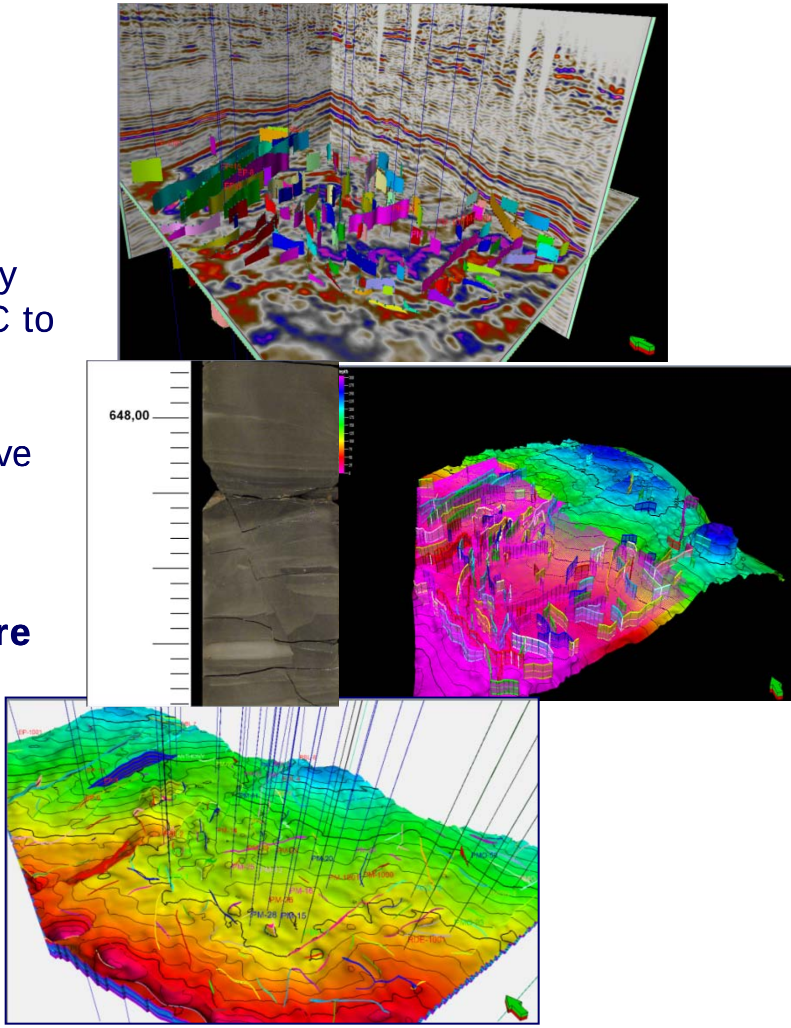
- La Tosca reservoir produces in the area of Pata Mora from fractured shallow water carbonates (extensive tectonic and diagenetic fracture network)

- Carbonate facies displaying secondary early diagenetic porosity (mainly oomoldic pores and diseccation micro-cracks) provide HC to the fracture network

- Best reservoir facies develop preferentially during the regressive portion of 5th order depositional cycles, where the presence of micro-fractures enhances matrix permeability.

- **For new wells to be successful in the area, both fracture and matrix components need to be encountered.**

- All of the modeled geological concepts were tested by dynamic simulations in an iterative procedure.



Grazie per l'attenzione