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Study of an Upper Cretaceous Source Rock Interval in the Middle Magdalena Valley Basin

SERVICIO GEOLÓGICO COLOMBIANO

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This presentation summarizes some results of an investigation by an interdisciplinary group of geoscientists with funding and leadership between the ANH and the SGC.

This list of participants from different research areas made important contributions to the results of this work (presenters are highlighted in bold letters).

Several sample analysis results were performed by laboratories from:

Universidad Industrial de Santander

UNIVERSIDAD NACIONAL DE COLOMBIA

Universidad de Caldas

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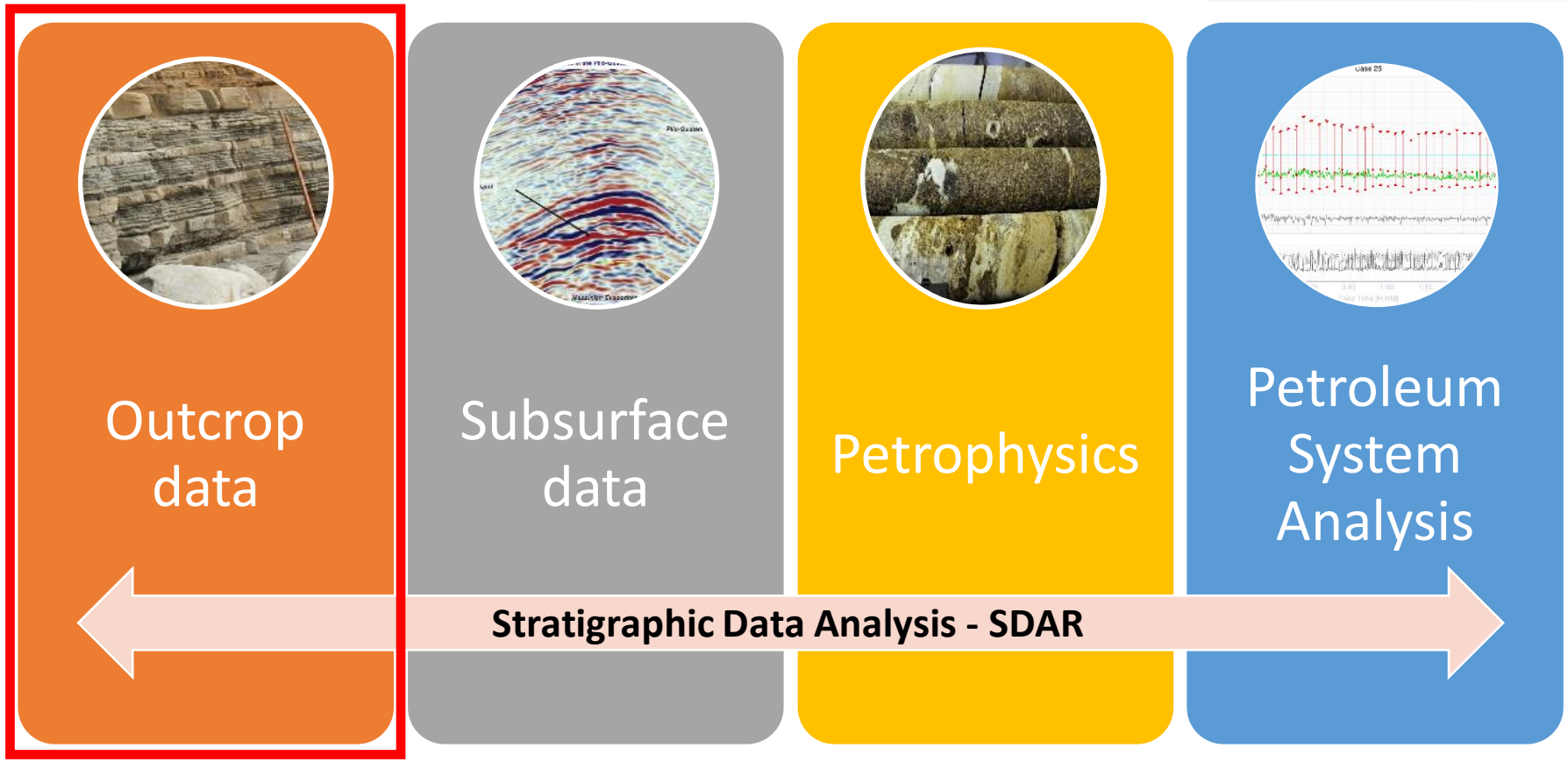
The goal of this study is to:

- Determine the stratigraphic intervals that show the best potential as unconventional plays in the northern part of the MMV basin based on geological information from outcrops and the subsurface

- Describe the structural and stratigraphic features of the northern part of the basin based on subsurface and outcrop data

- Propose a sweet spot concept based on geologic parameters and volumetric estimations for the unconventional resources of the Salada, Pujamana, and Galembo-La Renta formations



Integrate data to identify prospective intervals as Turonian-Santonian source rock reservoirs and its geochemical variations in the Middle Magdalena Valley Basin

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Geological Framework 1

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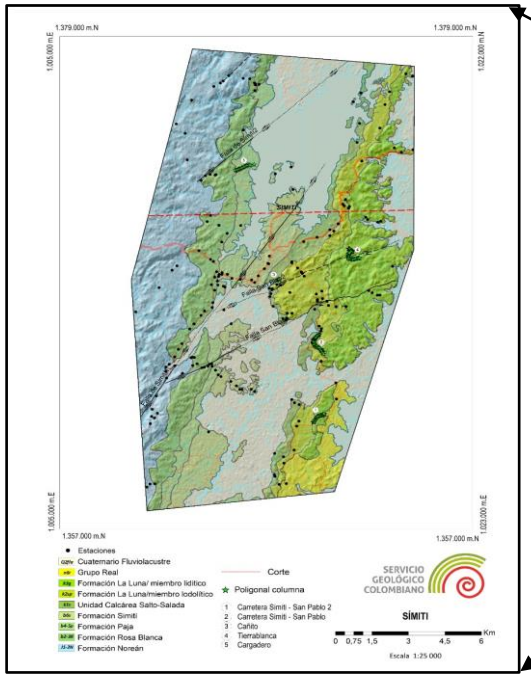

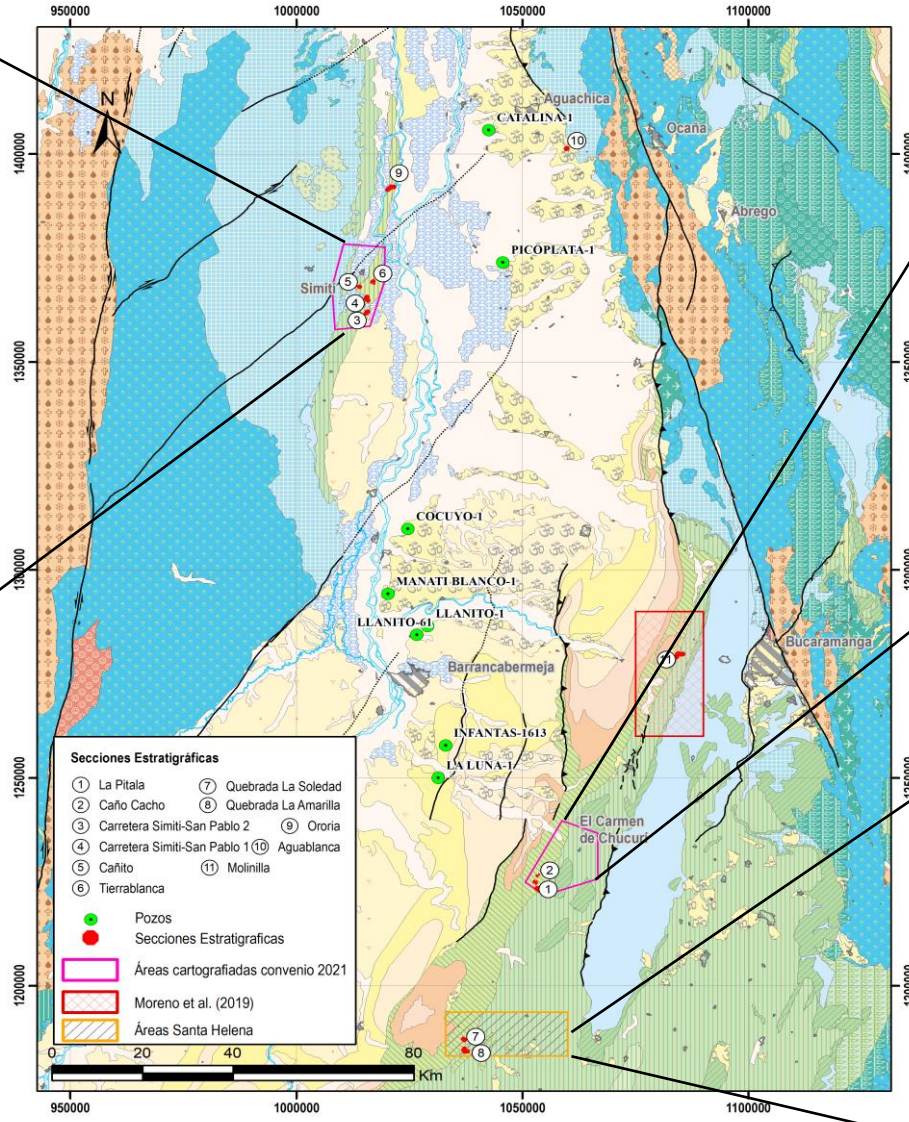

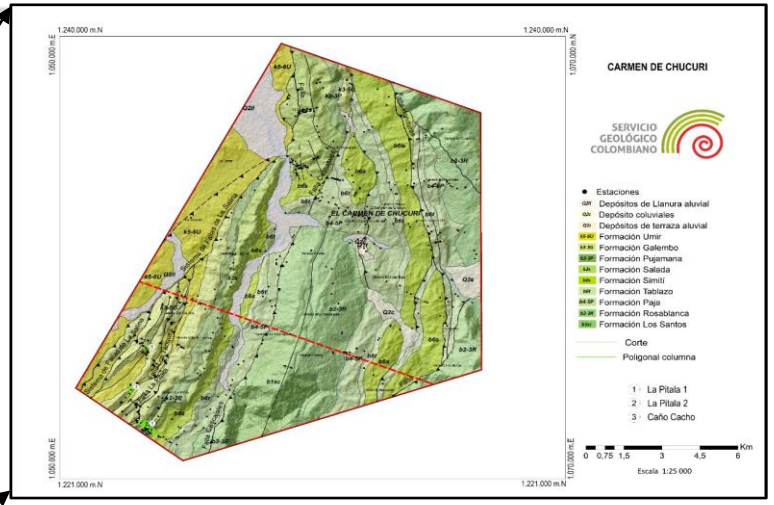

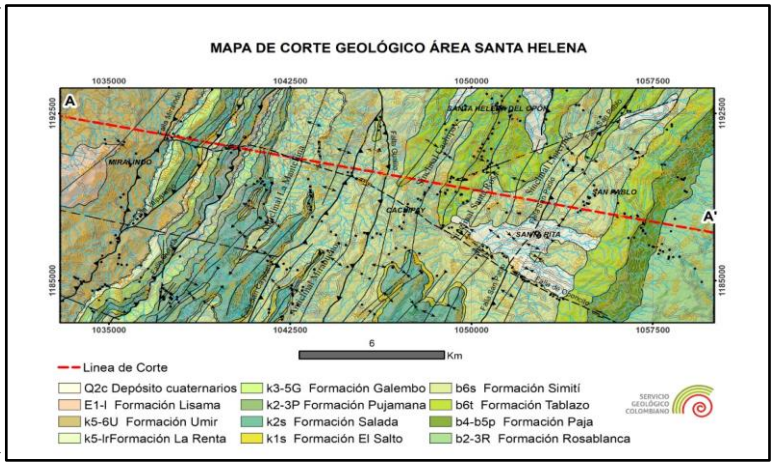

- 1185 field stations
- 586 Km^2 of geologic mapping
- 2280 m stratigraphic section

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Correlation – Using well-log information for regional correlations in fine-grain rocks

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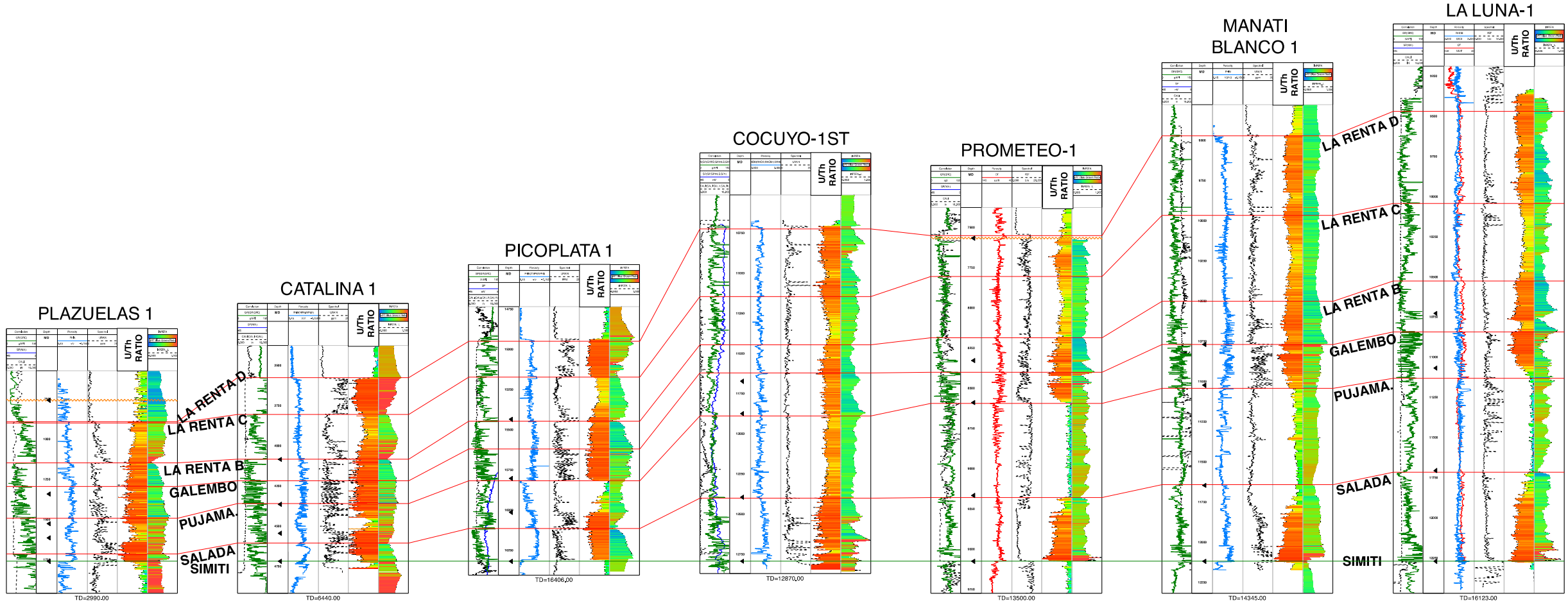
N

S



20 km

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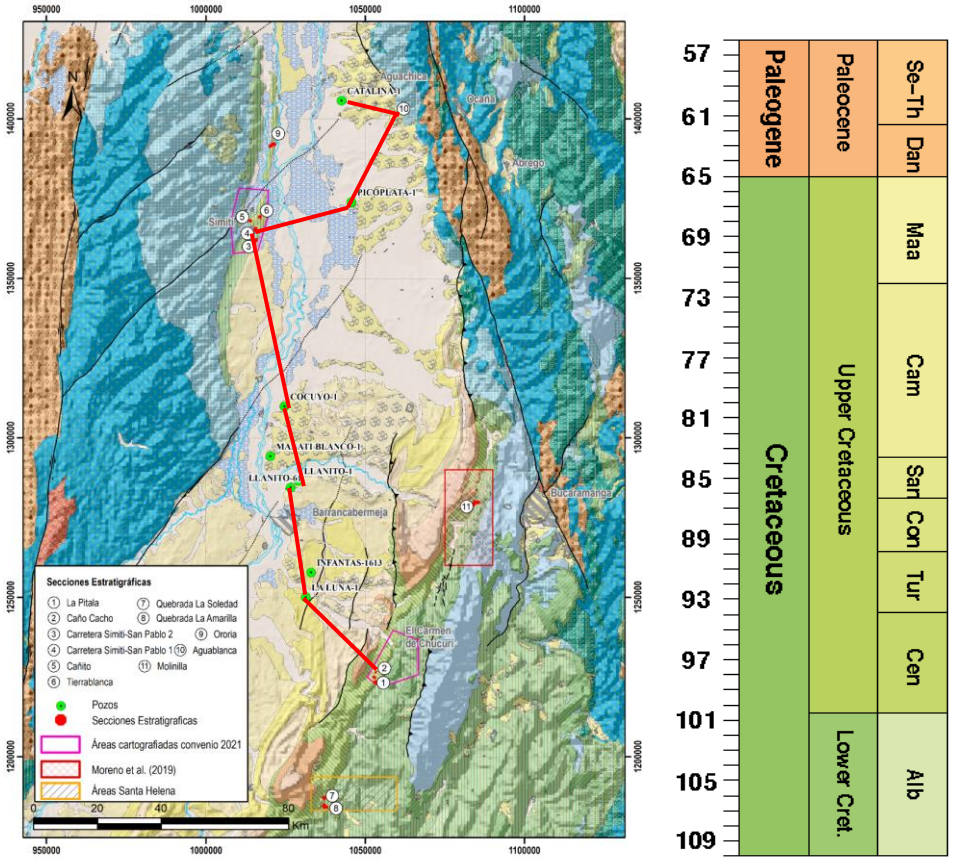
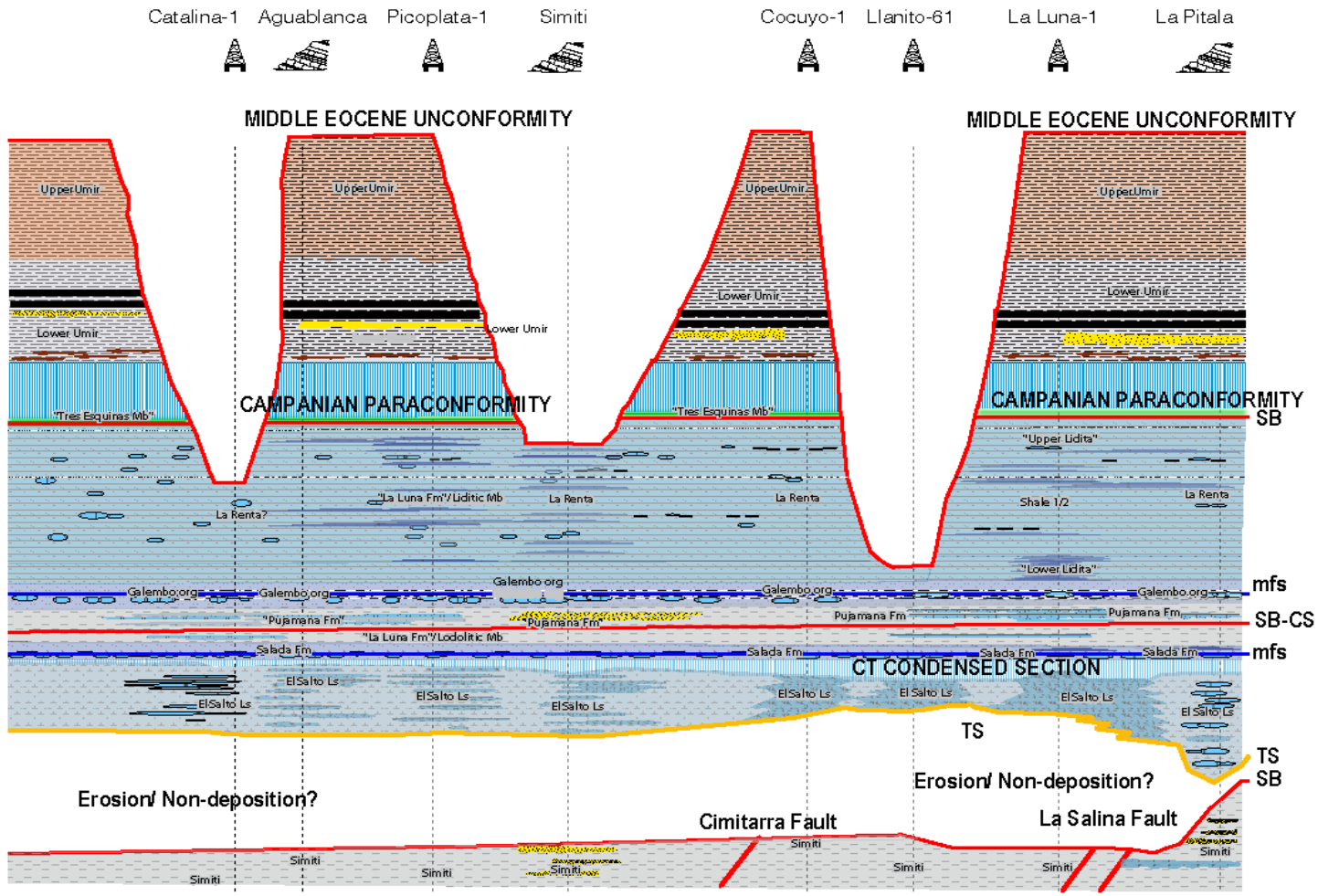
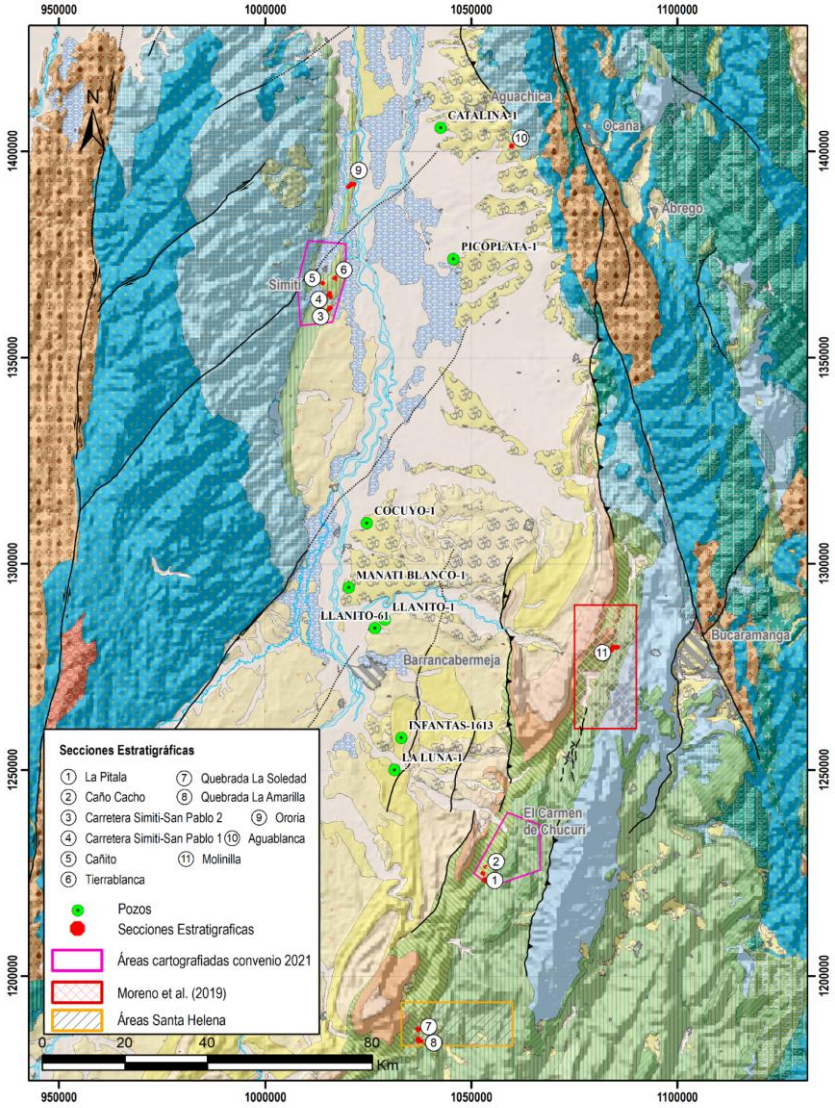
Chronostratigraphic Chart – Upper Cretaceous rocks MMV





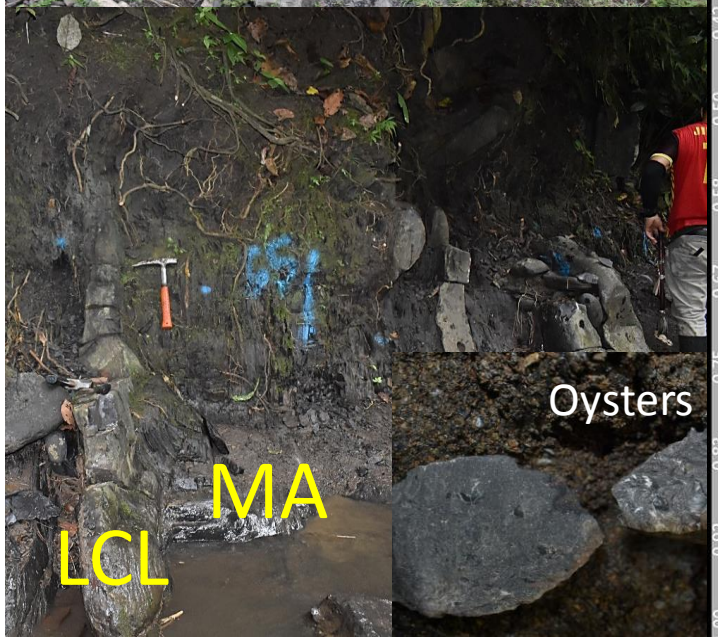
Stratigraphic information from outcrops and outcrops

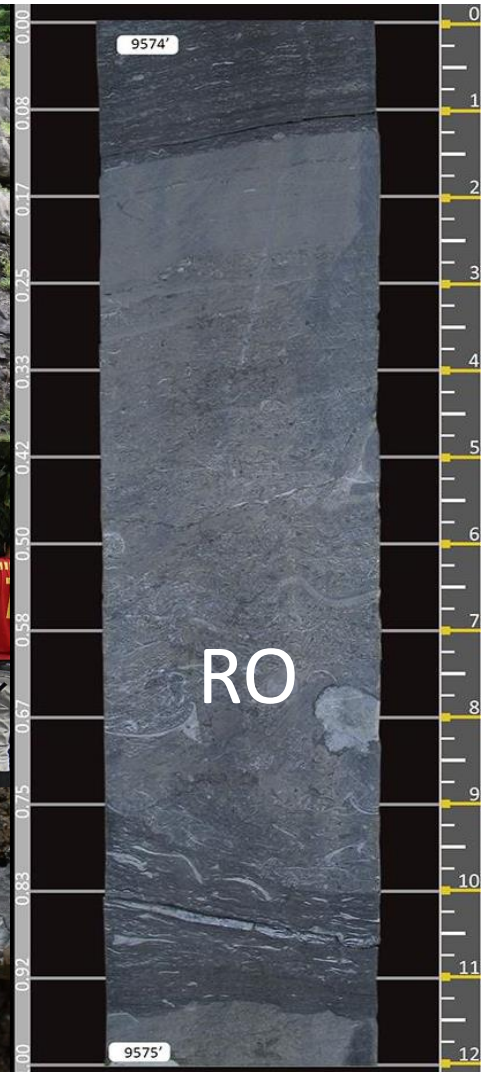


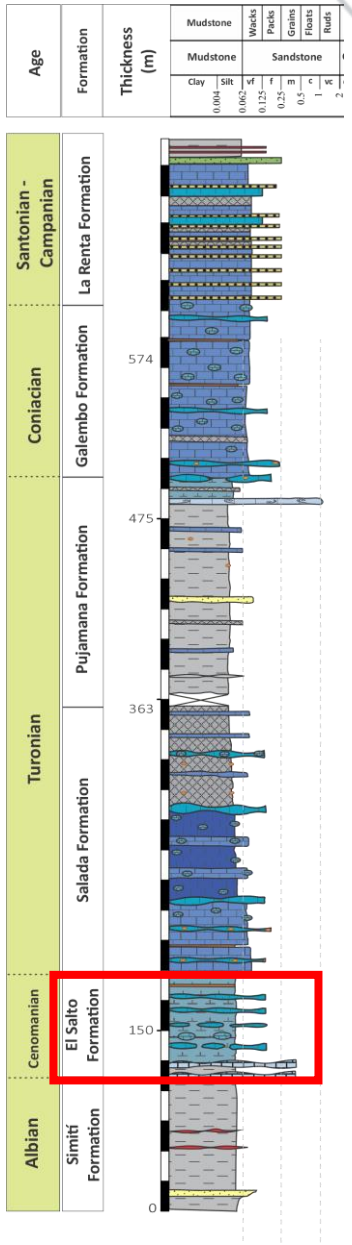
Wells: 2.160 feet

Stratigraphic sections: 2.280 meters

El Salto Formation (Middle Cenomanian)

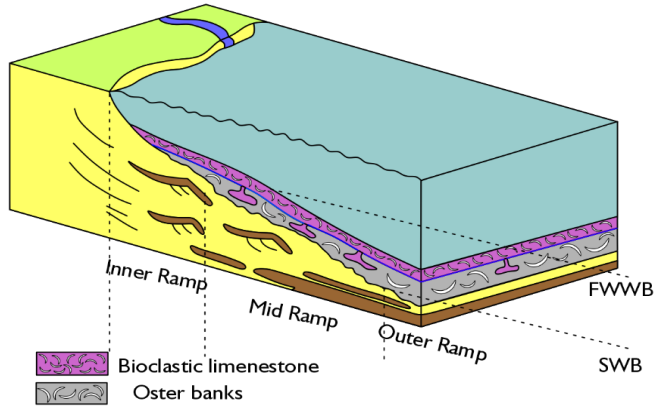






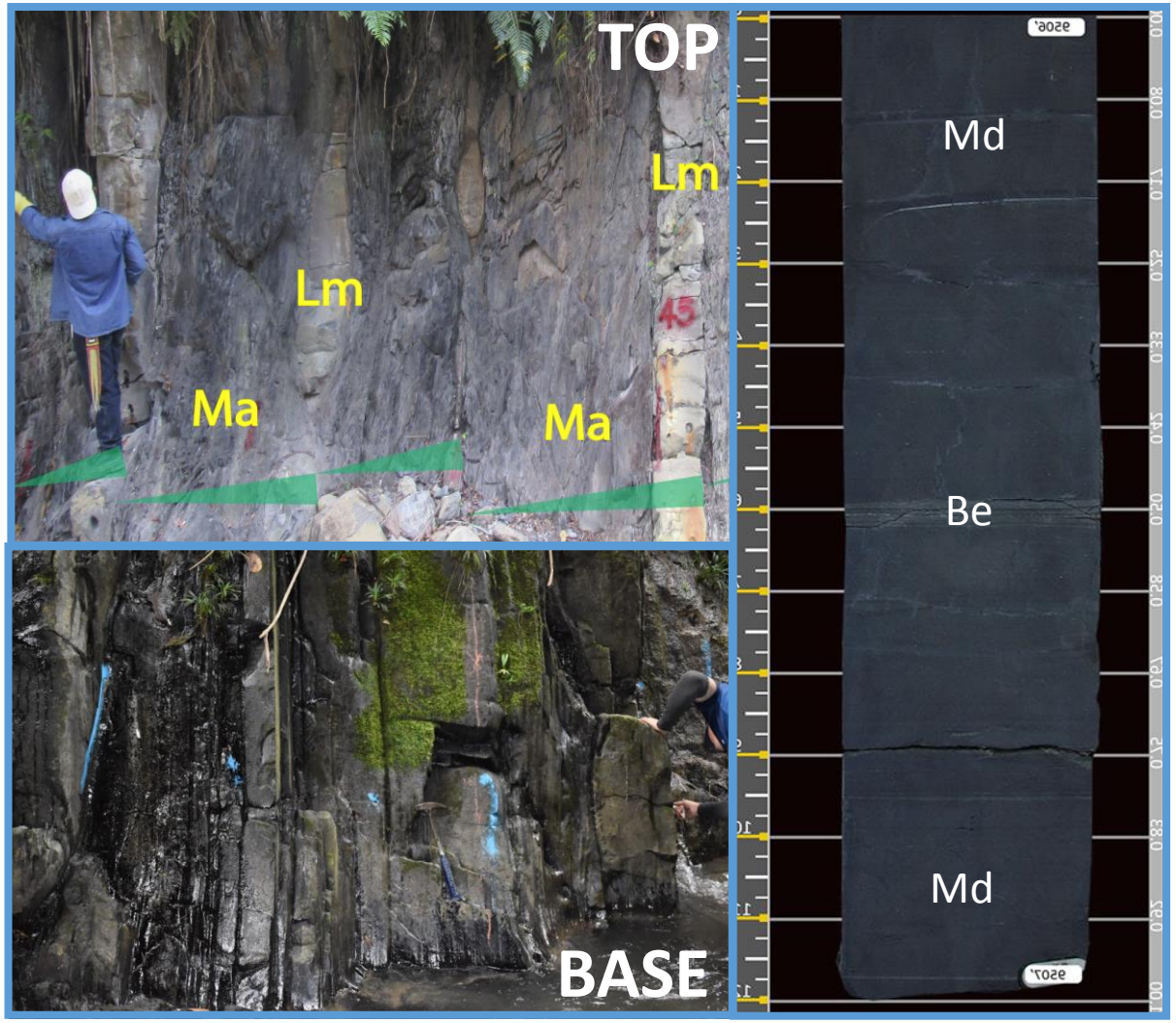
CENOMANIAN

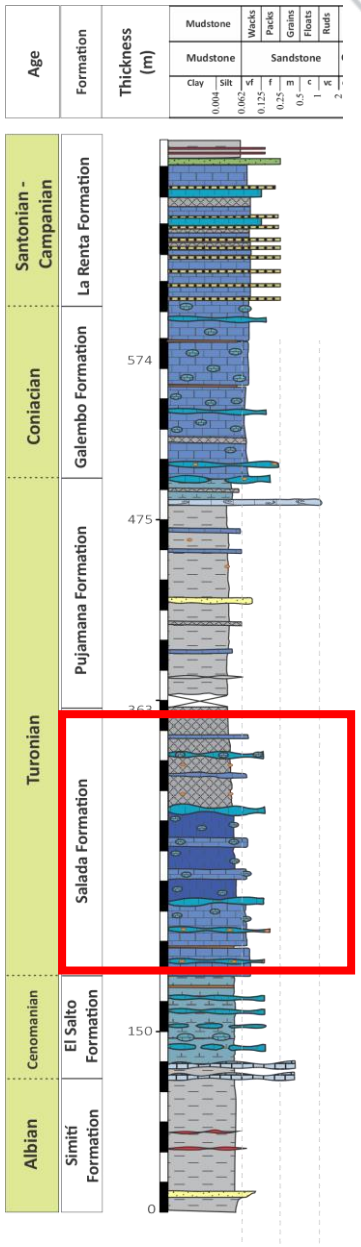
El Salto Formation
(Mixed Ramp)



FWWB: Fair weather wave base
SWB: Storm wave base

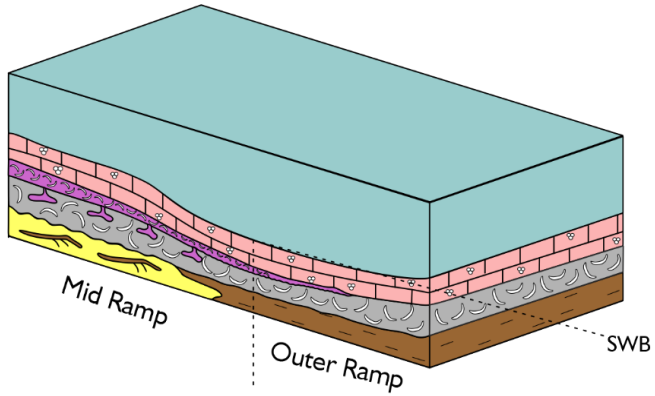
Salada Formation (Lower Turonian)





LOWER TURONIAN

Salada Formation
(Mixed Anoxic Ramp)



SWB: Storm wave base

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Pujamana Formation (Mid Turonian-Coniacian)

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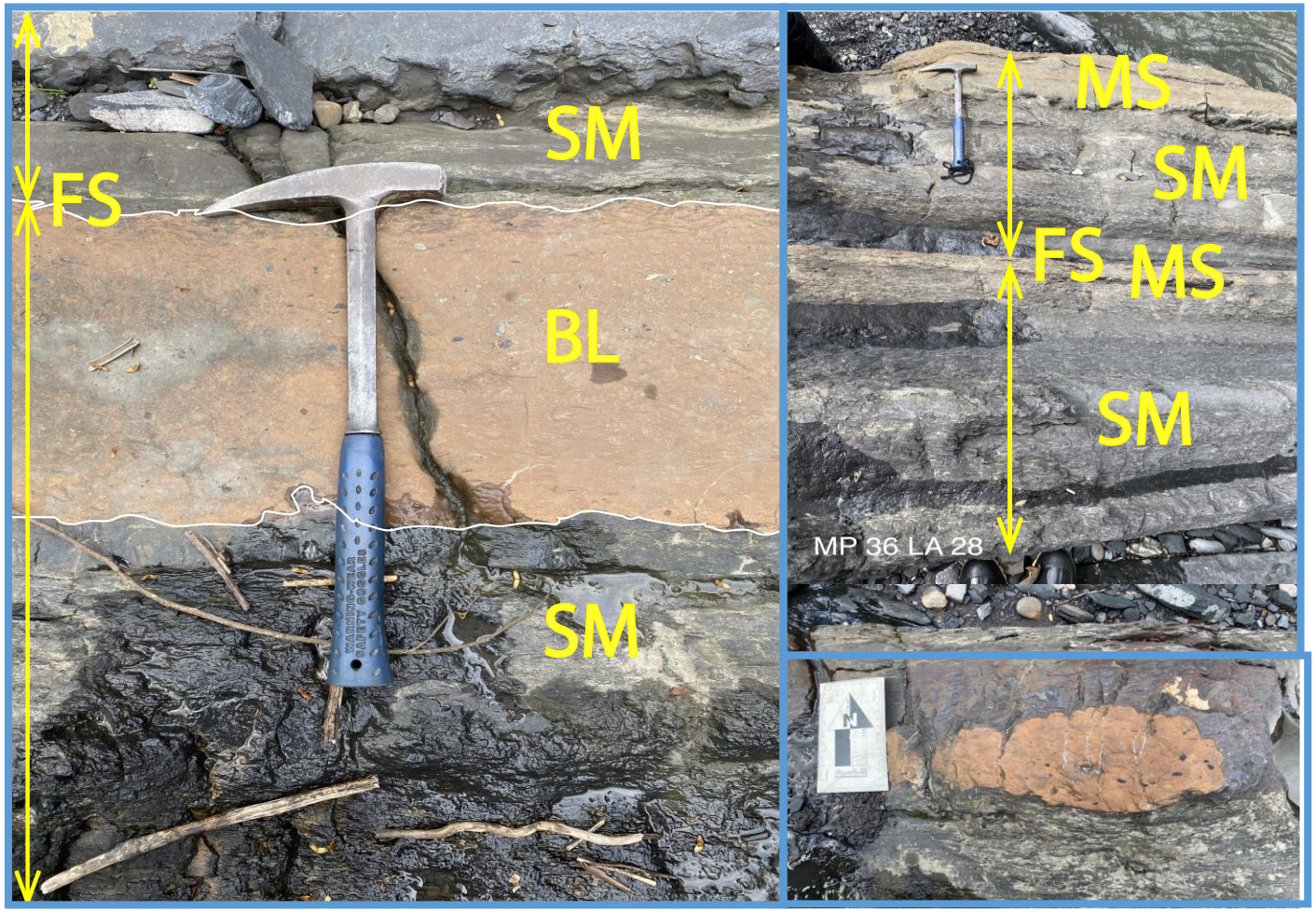
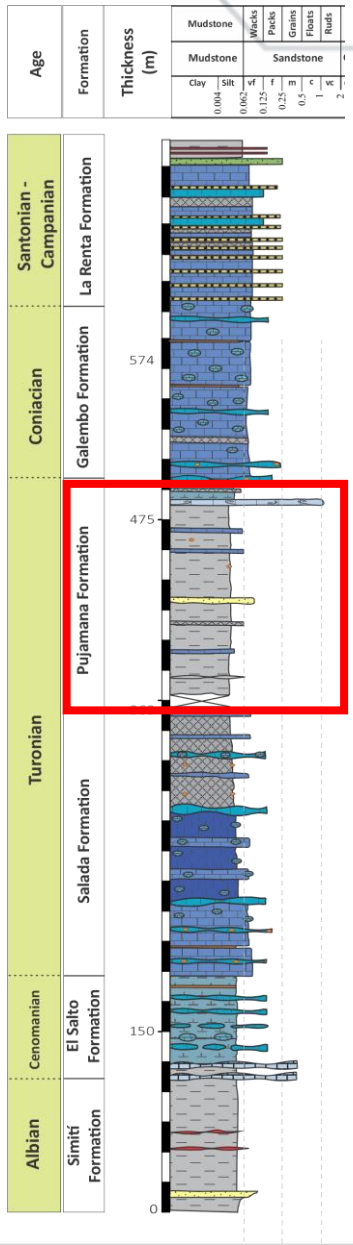
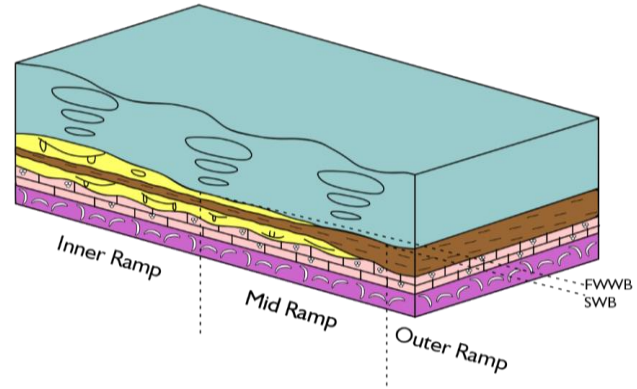




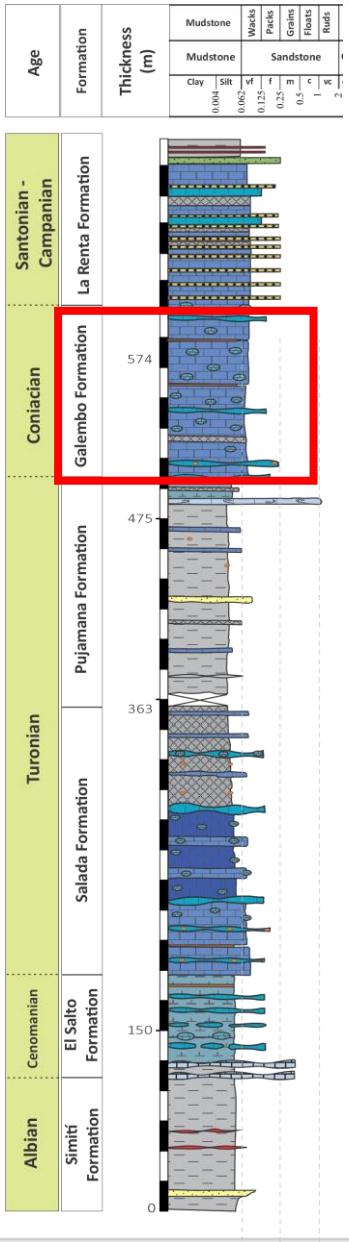
MIDDLE - UPPER TURONIAN

Pujamana Formation
(Siliciclastic Ramp)



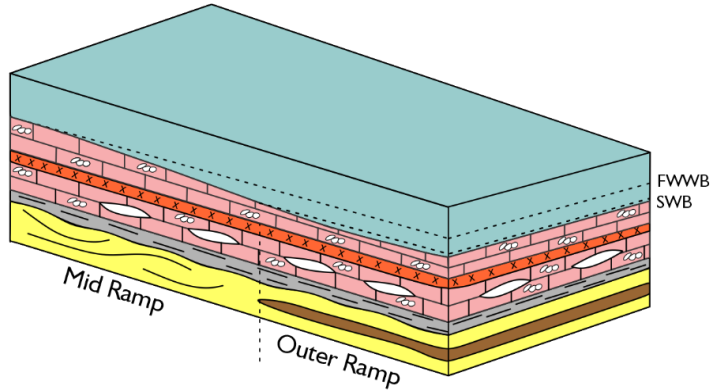
FWWB: Fair weather wave base
SWB: Storm wave base

Galembo Formation - organic rich (Coniacian)



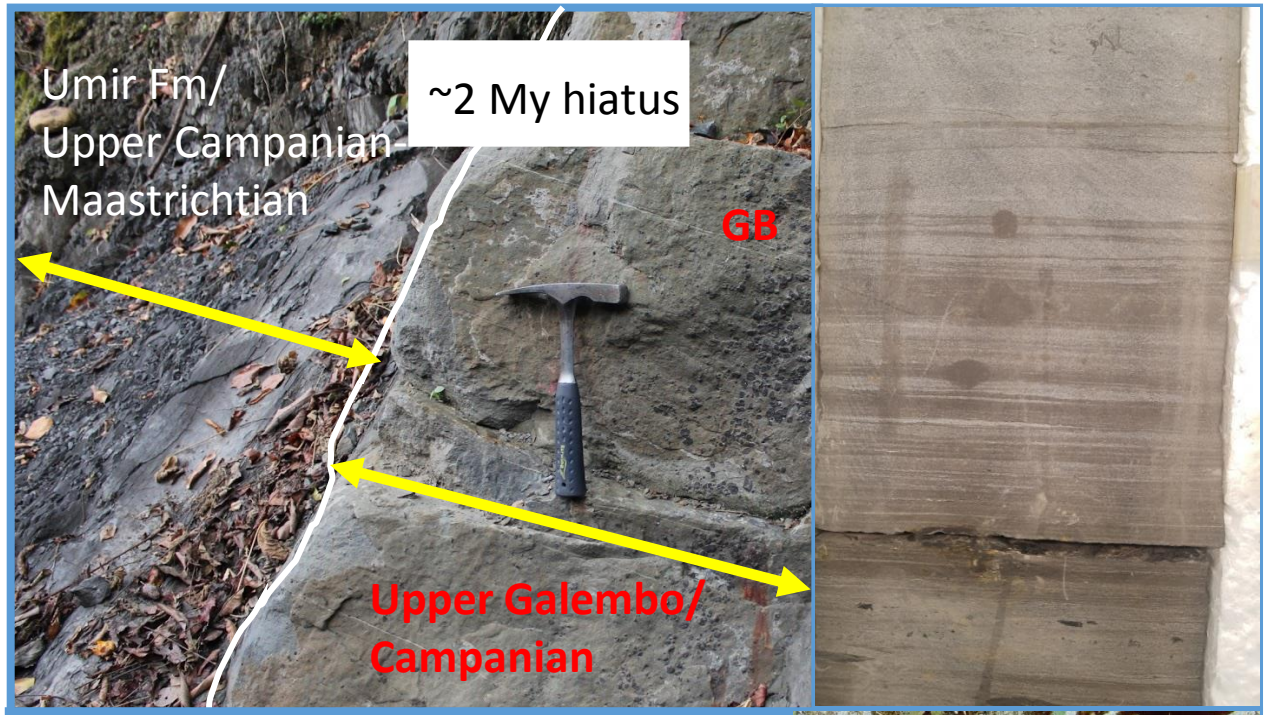
CONIACIAN

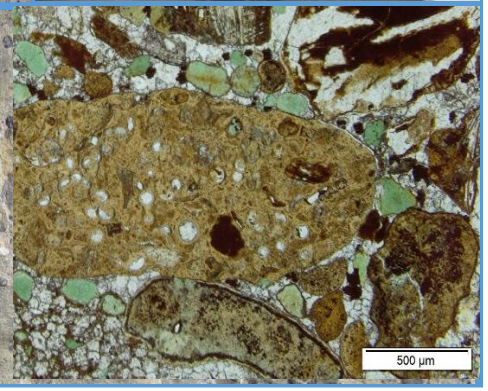
Galembo Formation
(Mixed Ramp)

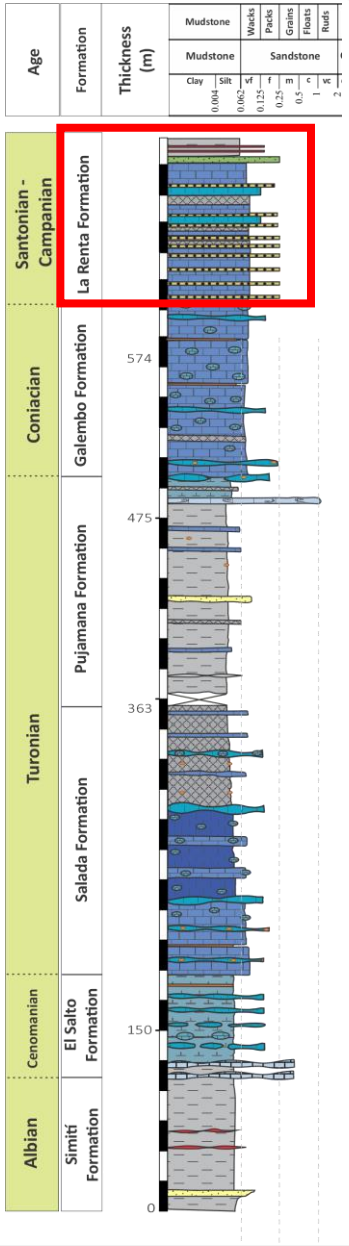


FWWB: Fair weather wave base
SWB: Storm wave base

La Renta Formation - phosphatic rich (Santonian/Campanian)

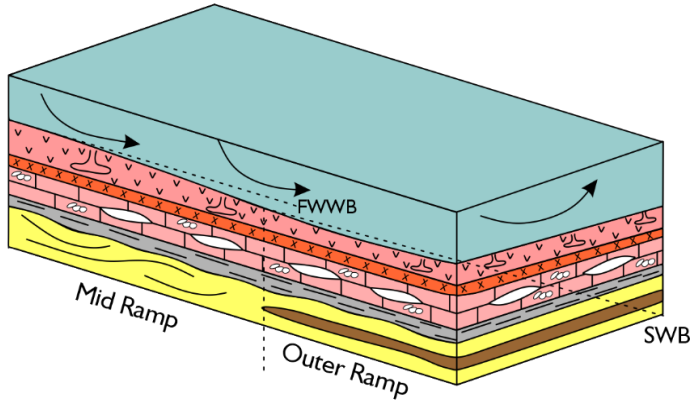




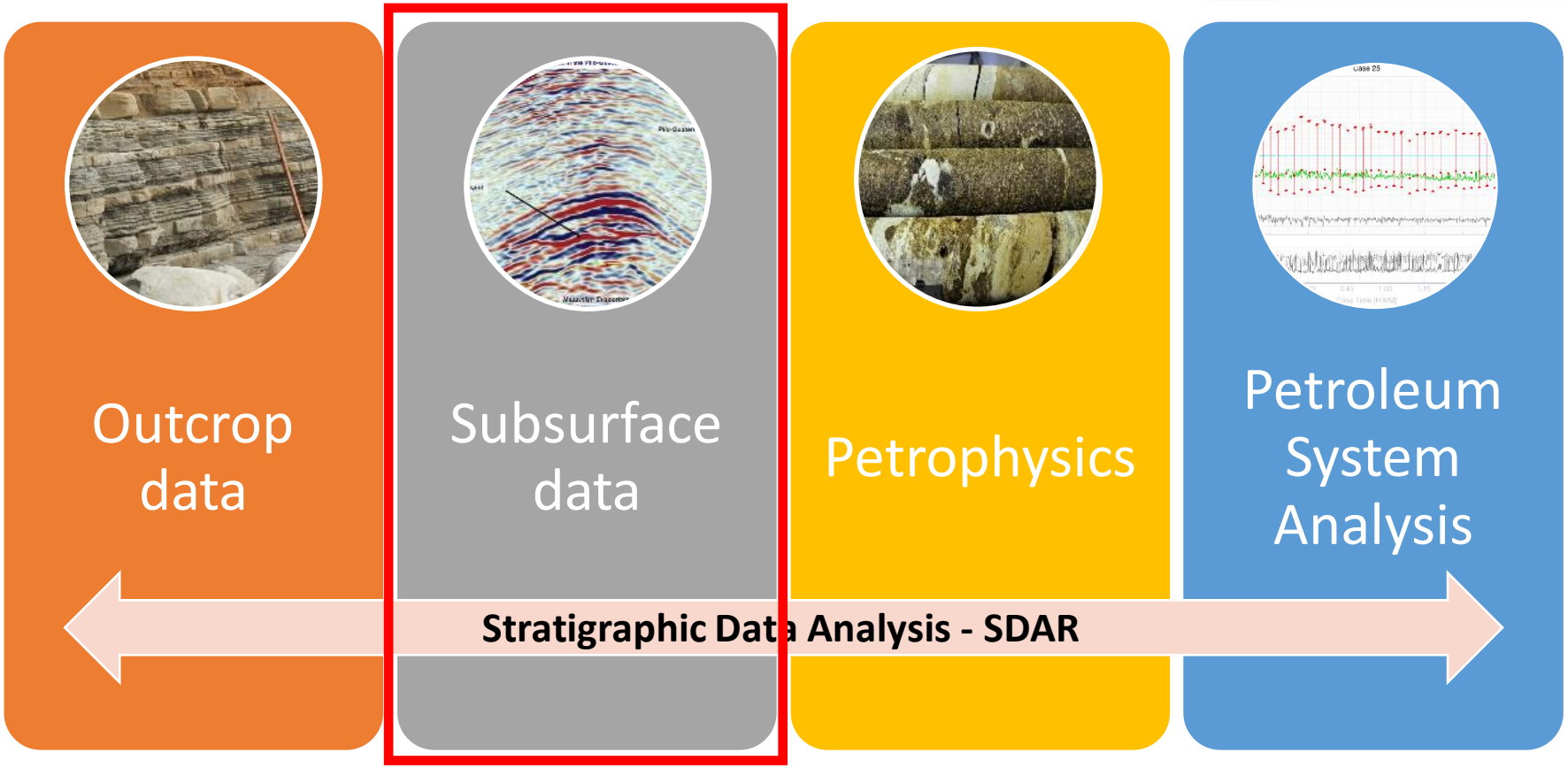


SANTONIAN - CAMPANIAN

La Renta Formation
(Carbonate ramp with bottom currents)



FWWB: Fair weather wave base
SWB: Storm wave base



Integrate data to identify prospective intervals as Turonian-Santonian source rock reservoirs and its geochemical variations in the Middle Magdalena Valley Basin

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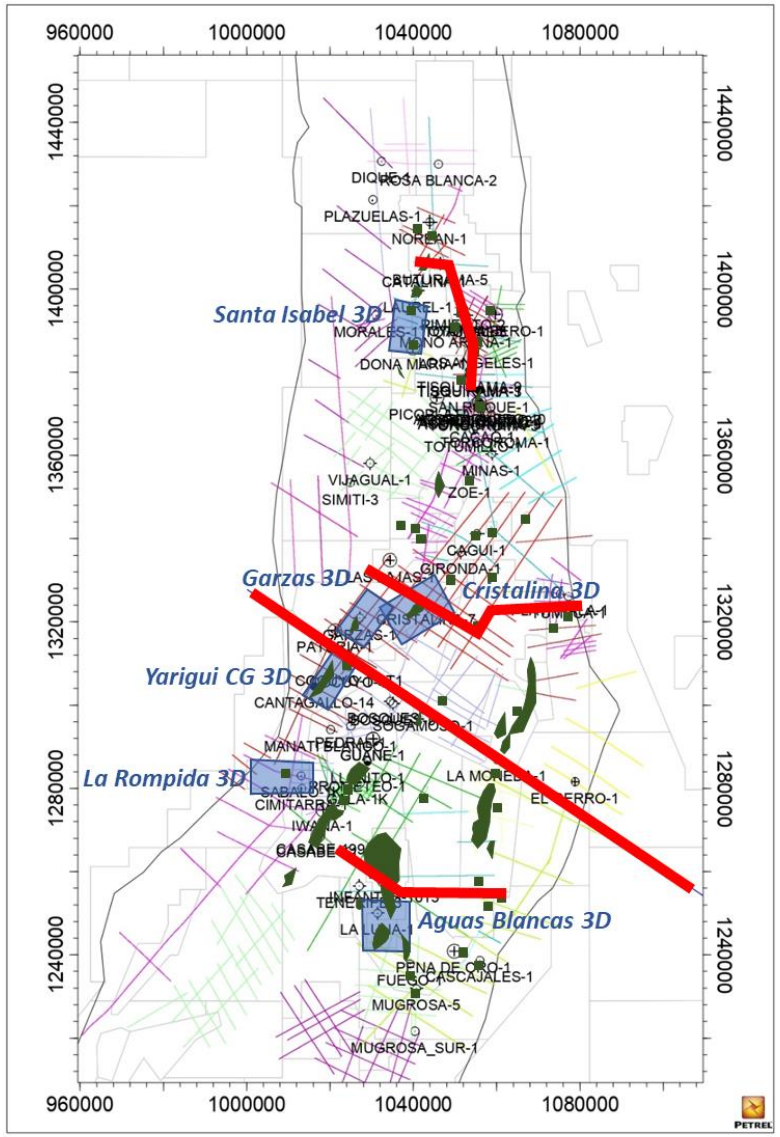
Seismic Interpretation - Data



- 15.000 km 2D seismic lines
- Six seismic volumes
- 69 wells

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Seismic Interpretation - Results

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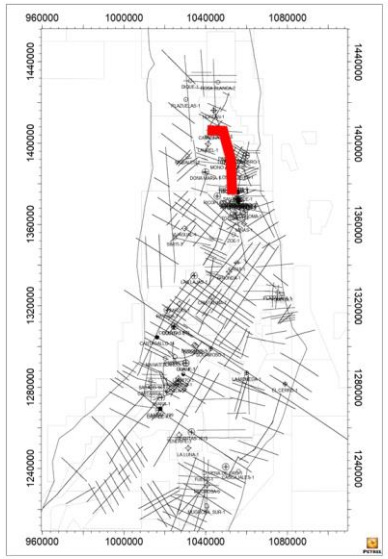

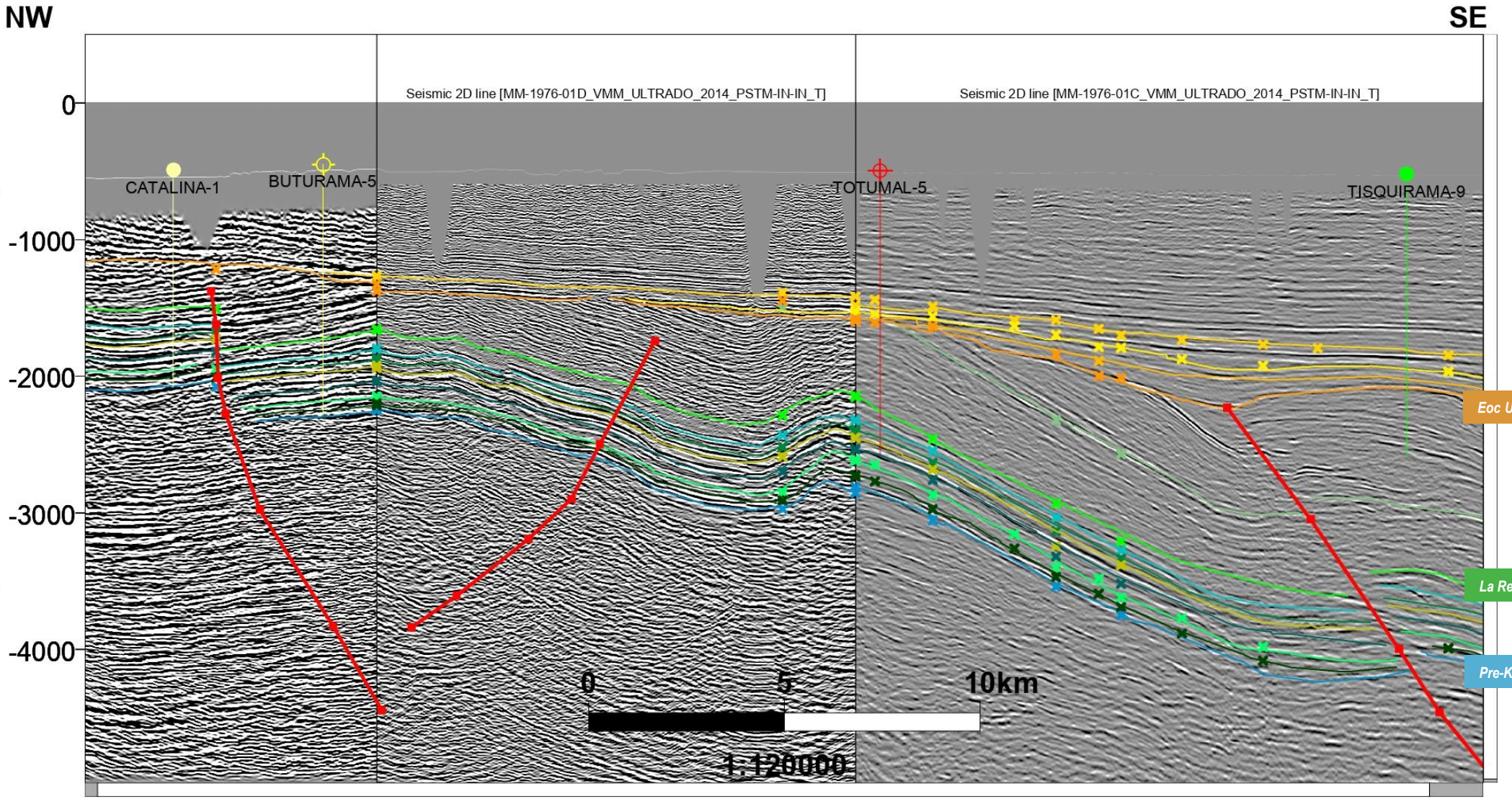

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Seismic Interpretation - Results

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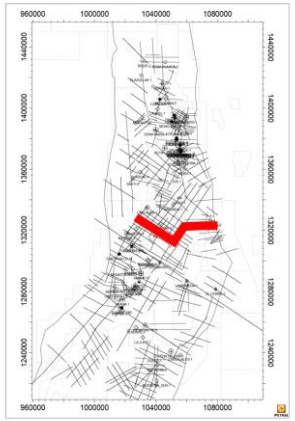

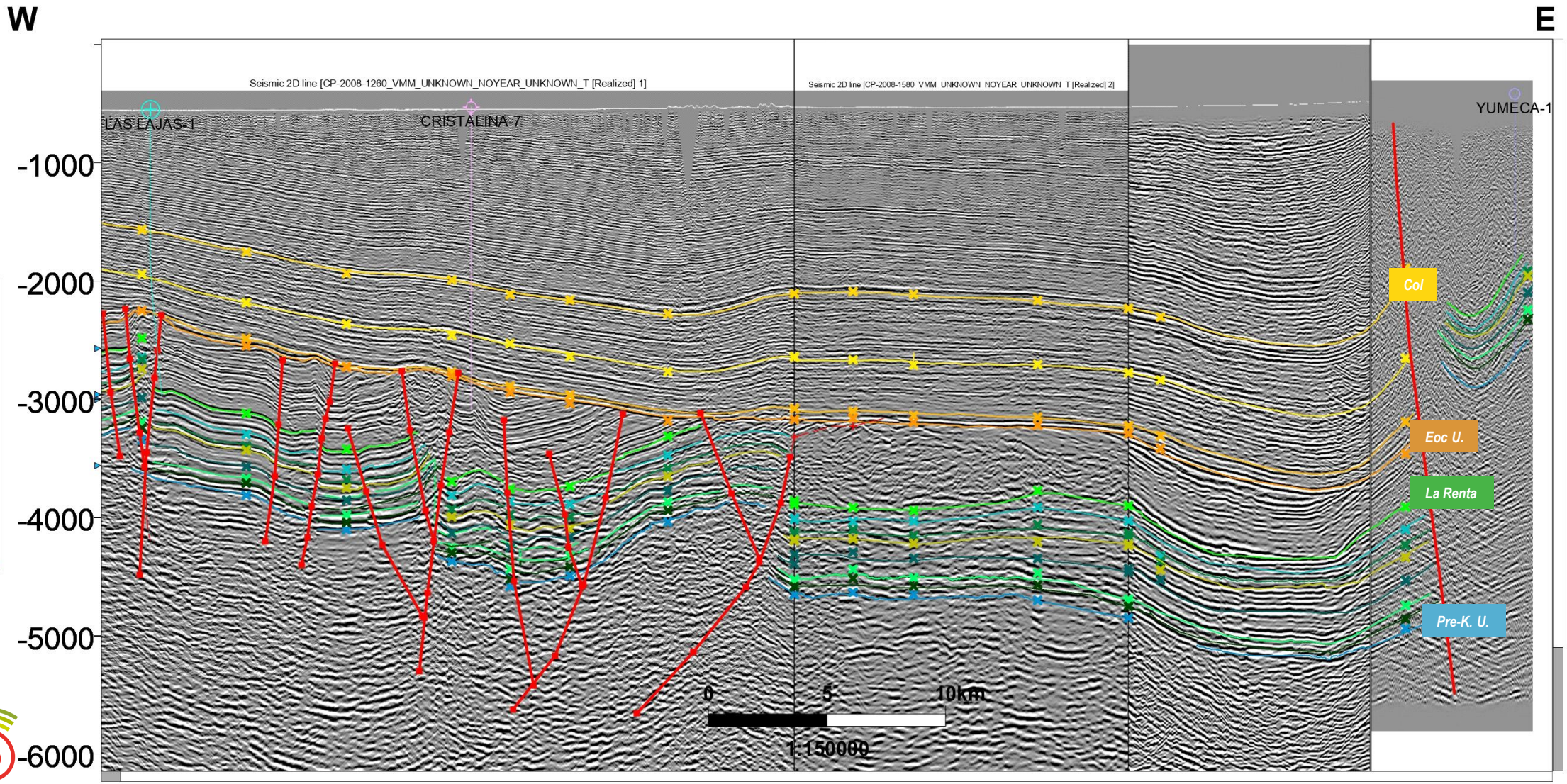

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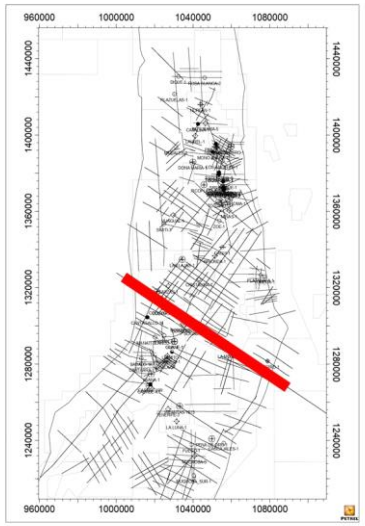
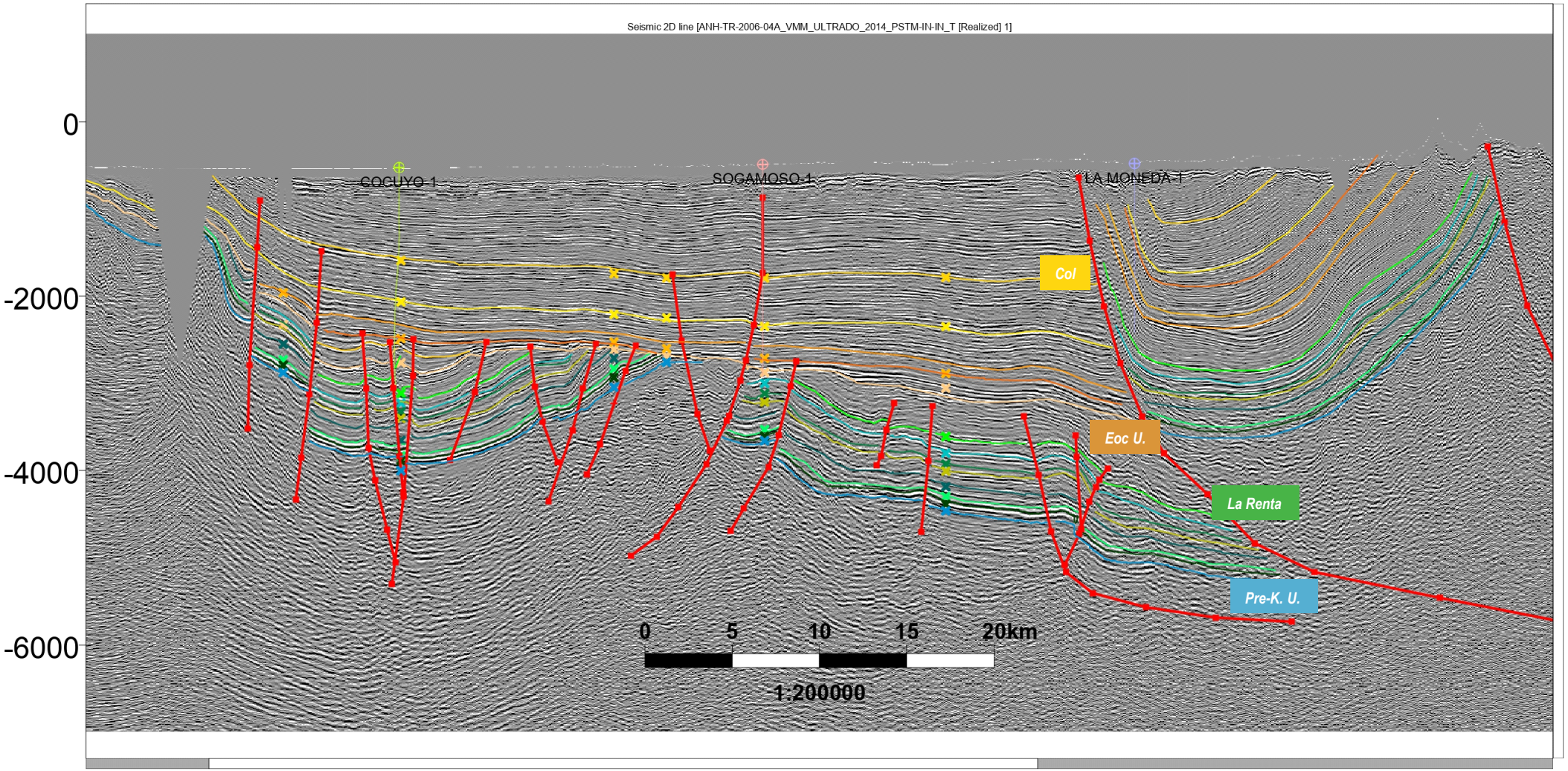


NW SE



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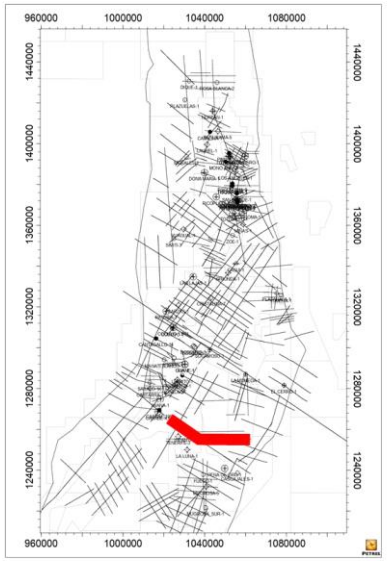

W

E

Seismic 2D line [DM-1987-1630_VMM_UNKNOWN_NOYEAR_PSTM-IN-IN_T [Realized] 1]

Seismic 2D line [N-1976-22_N-1976-22A_T-1976-18-MERGE_VMM_ARCIS_2012_PSTM-IN-IN_T]

INFANTAS-1613

0
-1000
-2000
-3000
-4000
-5000

Col

Eoc U.

La Renta

Pre-K. U.

0 5 10km

1:100000

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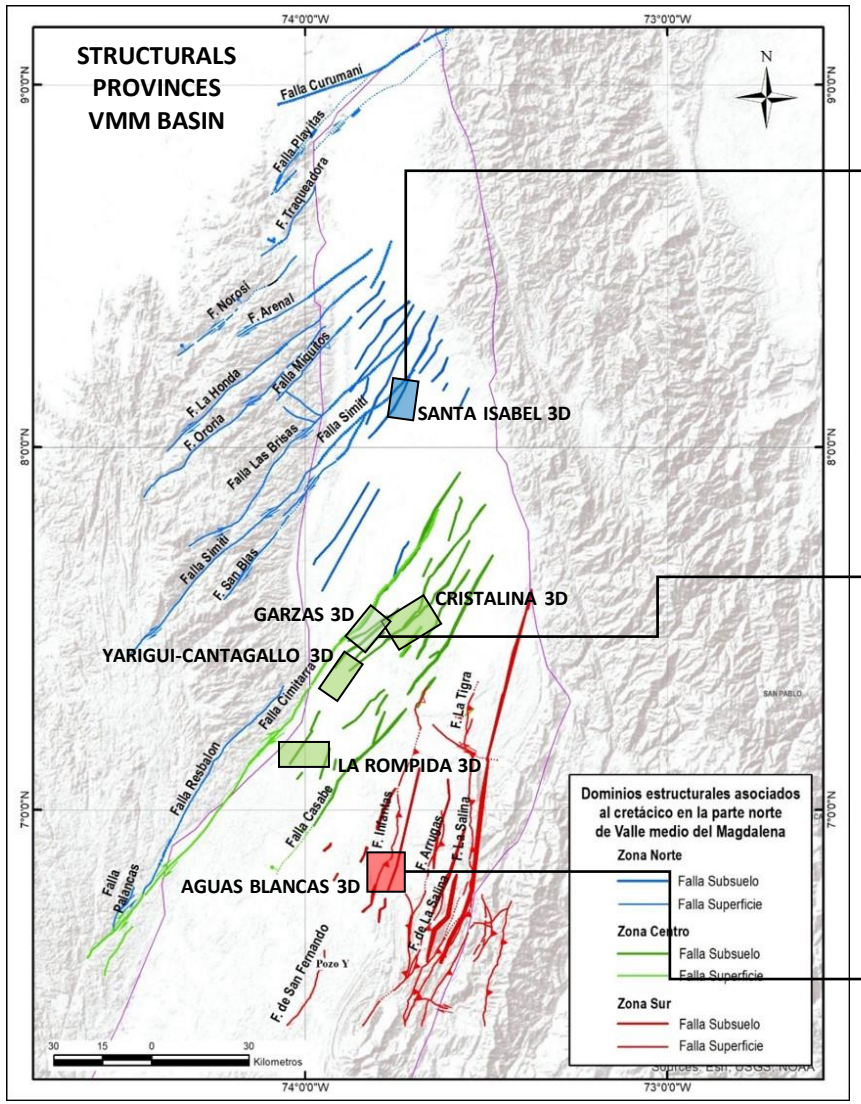
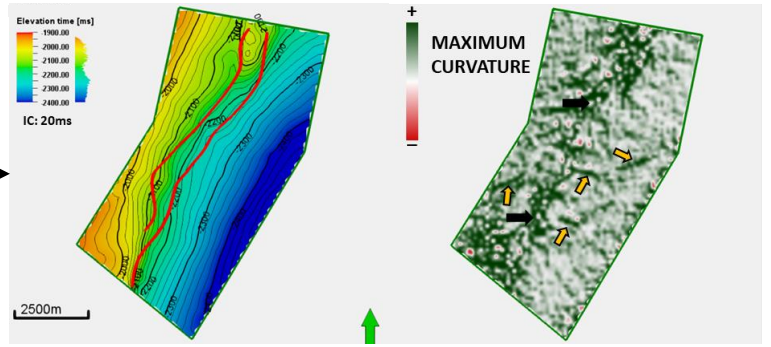
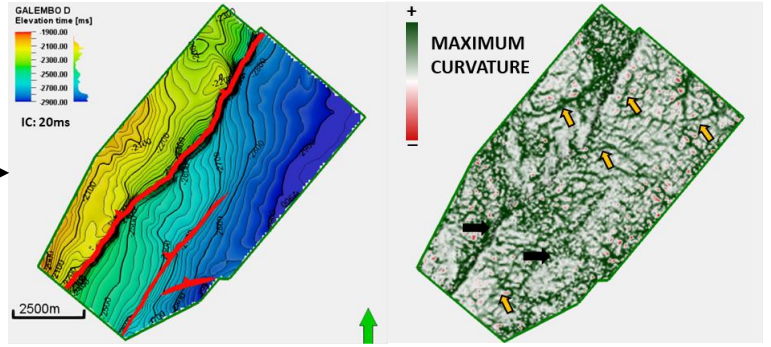
Seismic Interpretation - Results



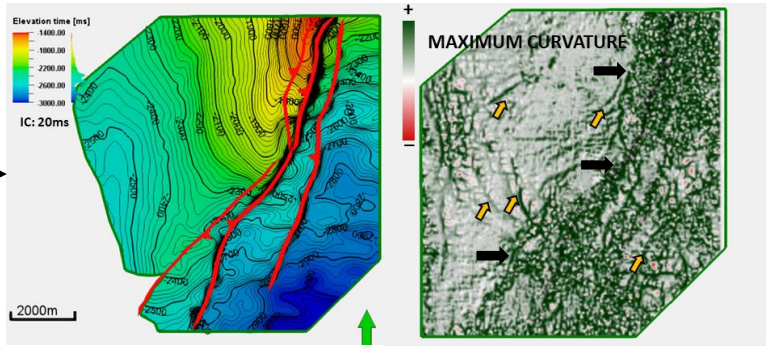
SANTA ISABEL 3D



GARZAS 3D



AGUAS BLANCAS 3D



Structural Map [TWT] and Maximun Curvature Attribute in 3D seismic volumen at LA RENTA Formation

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Seismic Interpretation - Results

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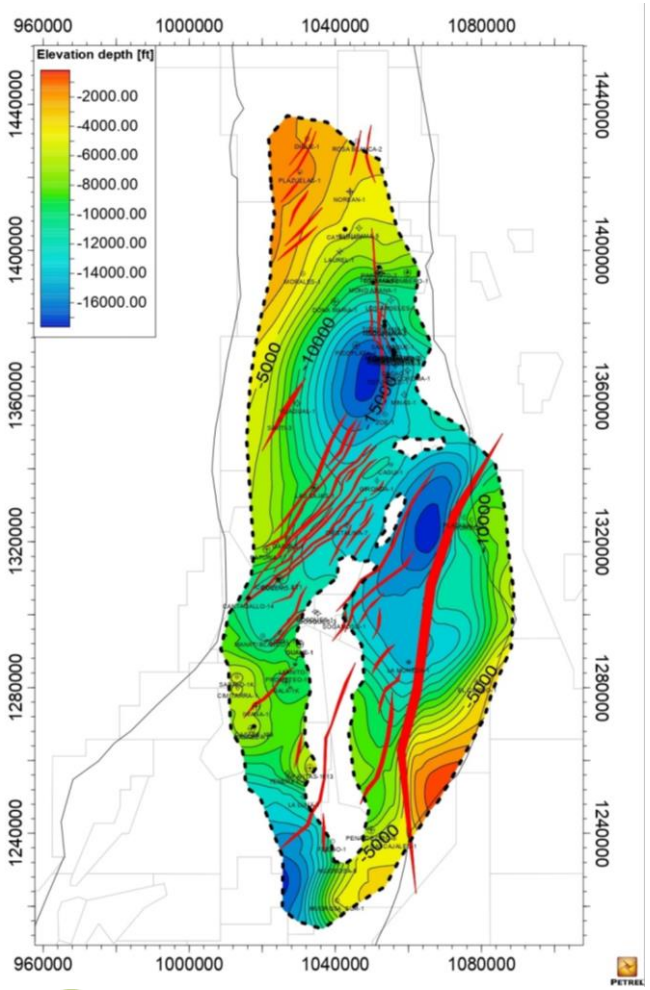
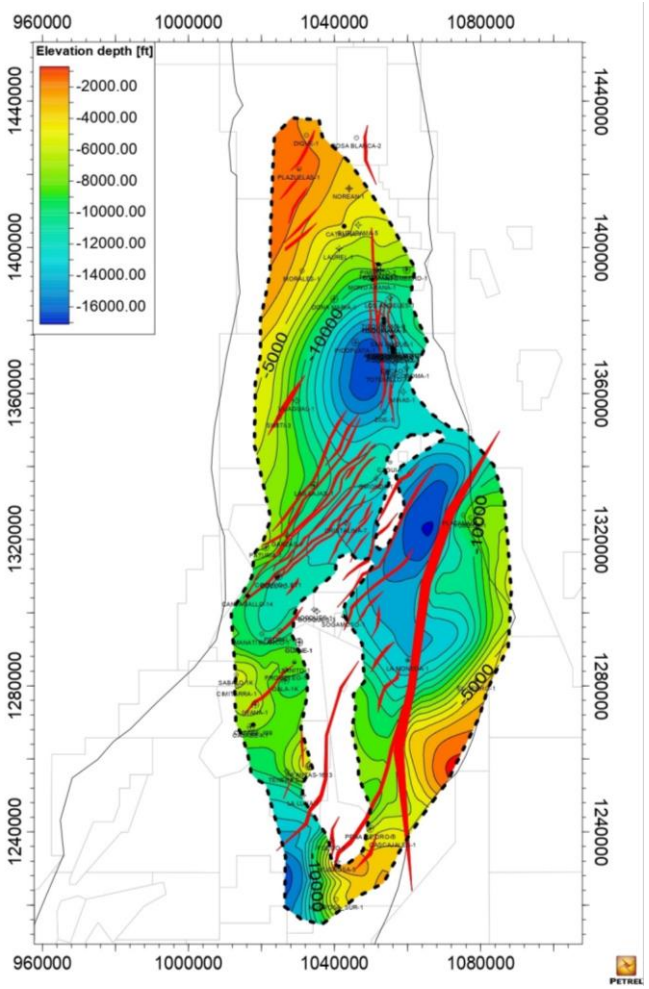
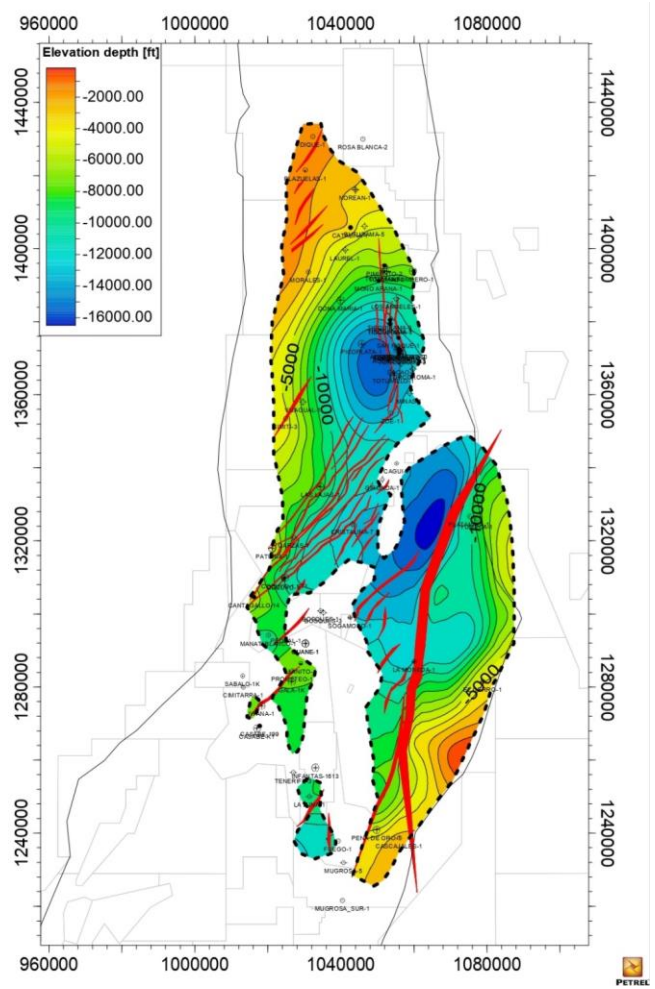
Structural maps



Salada Formation



Pujamana Formation



La Renta Formation

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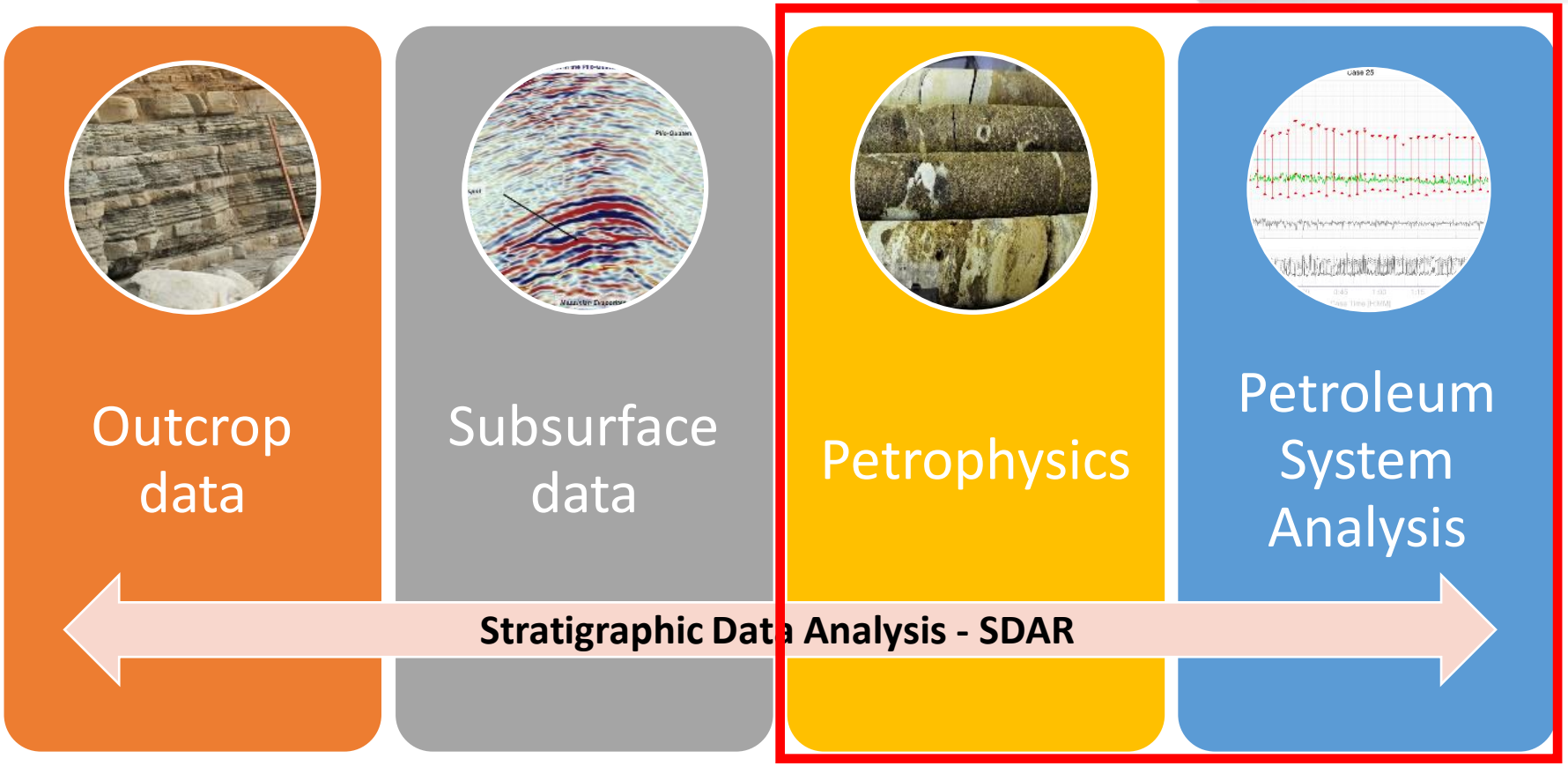
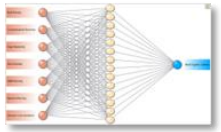


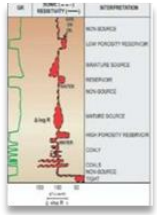
Integrate data to identify prospective intervals as Turonian-Santonian source rock reservoirs and its geochemical variations in the Middle Magdalena Valley Basin

Petrophysics - Methodology

Log Quality Control.
Standardization Mnemonics of the curves

Petrophysical Evaluation of the Source Rock Reservoir



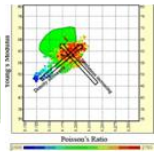


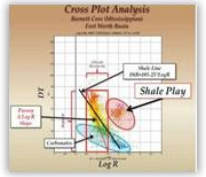
Using Passey, Schmoker, Uranium content, Neural Networds or other methods

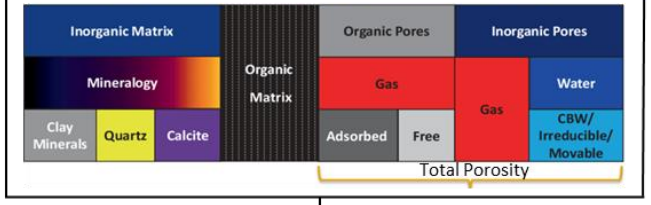
Estimate Total Organic Content Profile

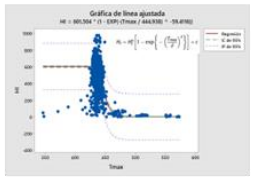
Output Computed Log Profiles: Mineral Volume, TOC, Porosity, Water Sat. Permeability and BI. Temp & Press

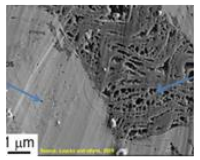
Estimate Geomechanical Properties



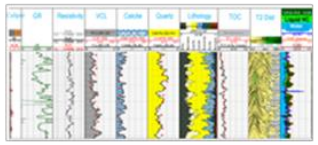




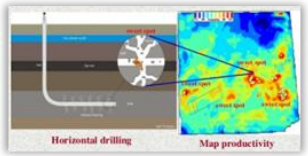


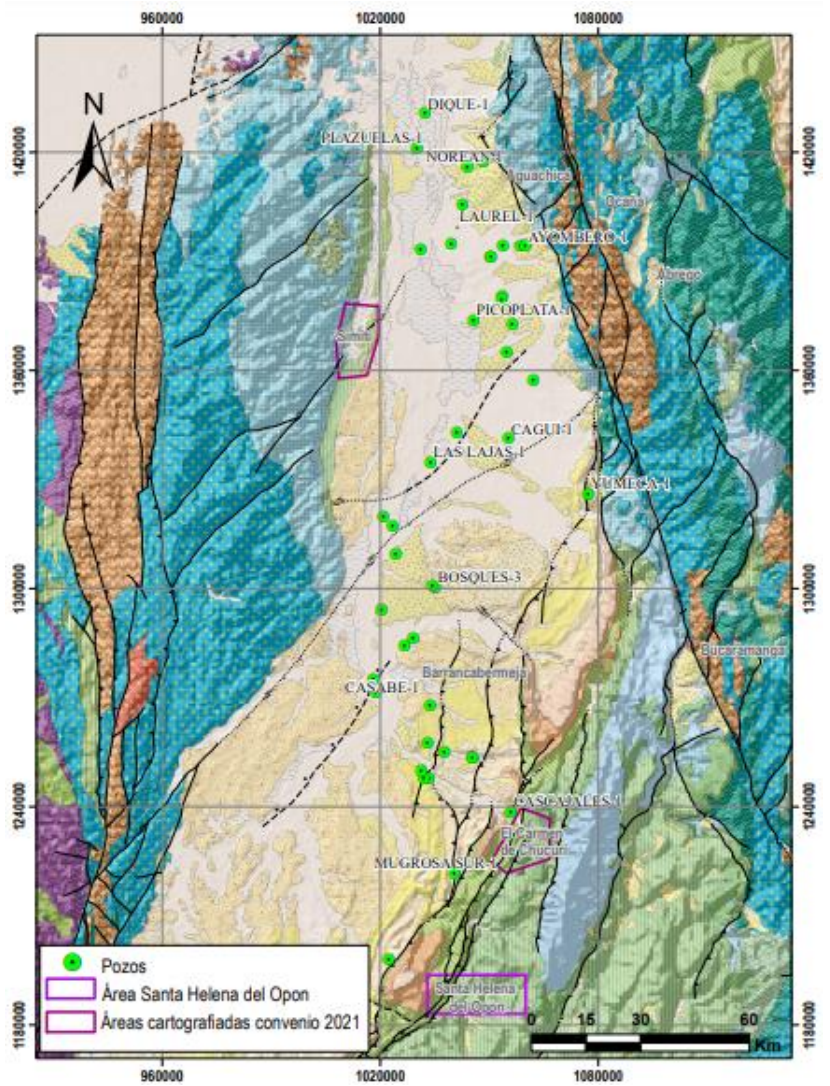


Convergence check of mineral solver results: core/cutting/swc , organic content, grain density, water sat from Lab analysis and formation test



Identify Prospective Intervals (Sweet Spots) using analogous play cutoff criteria: Sedimentological, Geochemical, Petrophysical and Geomechanical.





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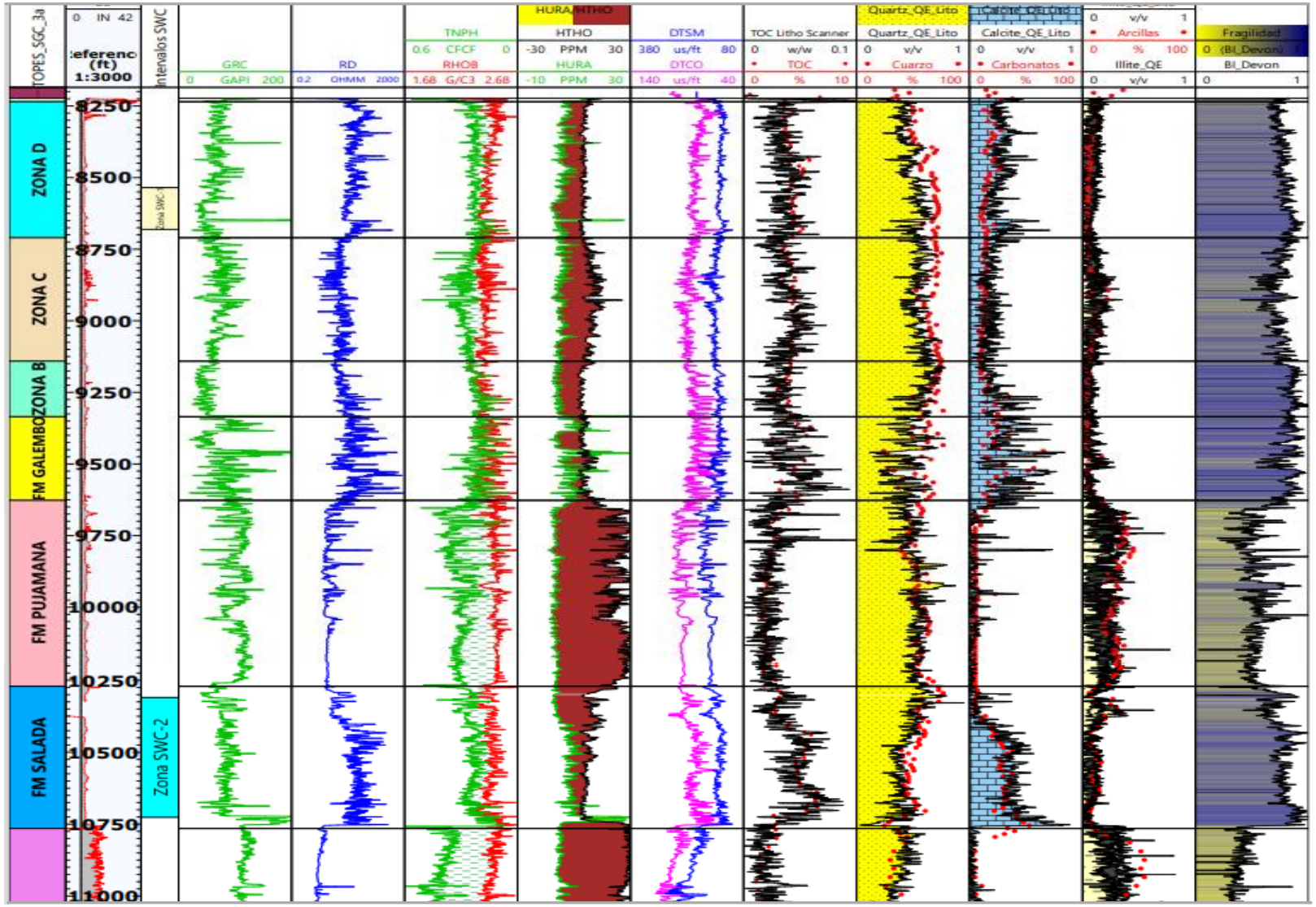
Petrophysics - Methodology



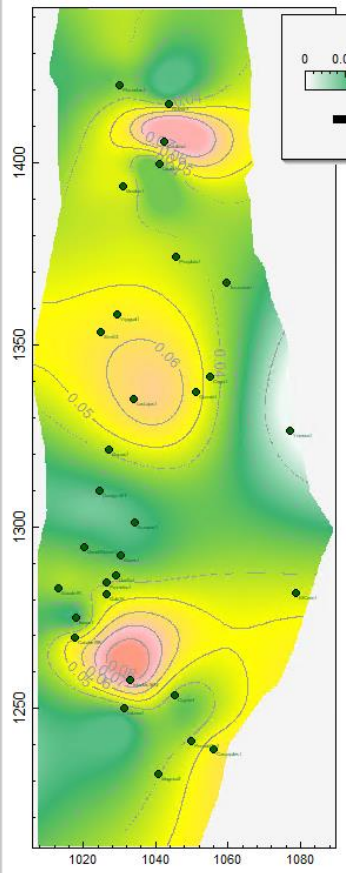
40 evaluated wells in three Upper Cretaceous rocks (so-called “La Luna Formation”): Salada, Pujamana and Galembo-La Renta formations

Adjustments with lab measurements: XRD, TOC, Pyrolysis, Porosity, Permeability, Grain Density

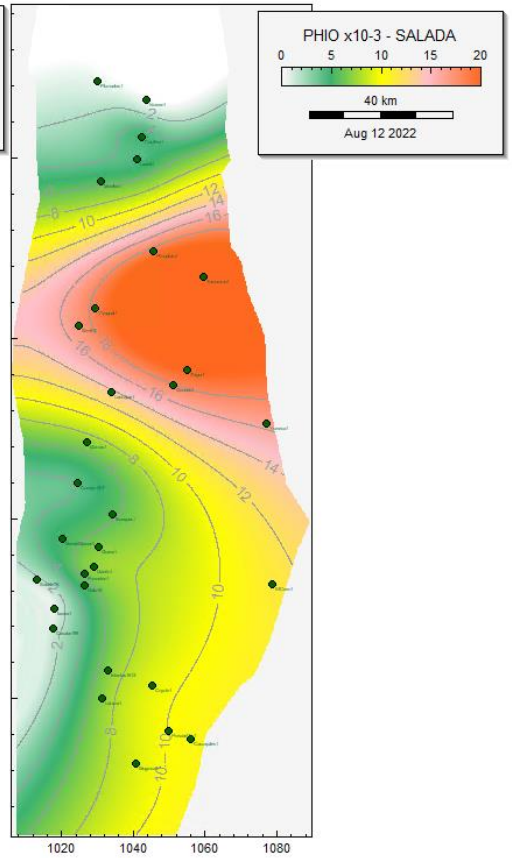
XRD: Database with 1.400 analysis from wells and outcrops

Pyrolysis: Database with 5.000 analysis from wells and outcrops

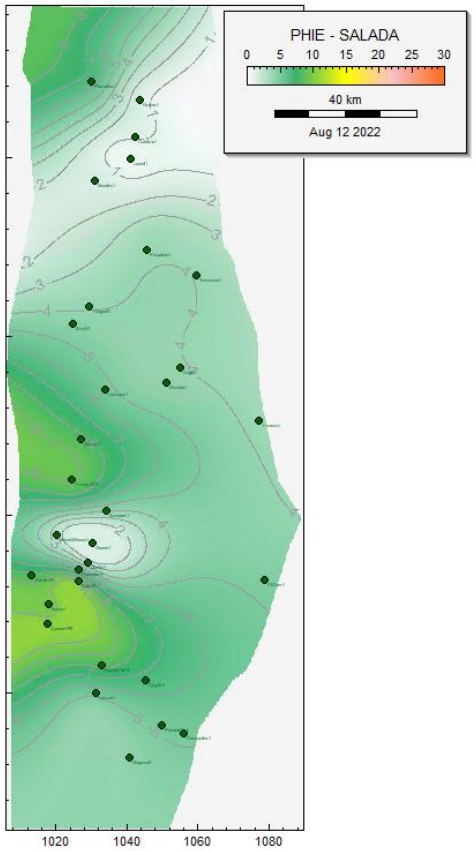
Petrophysics - Results



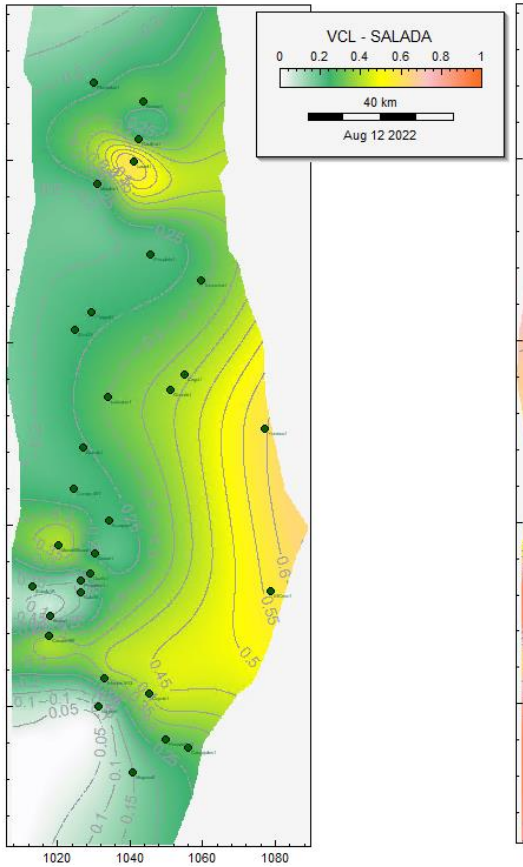
TOC (%)



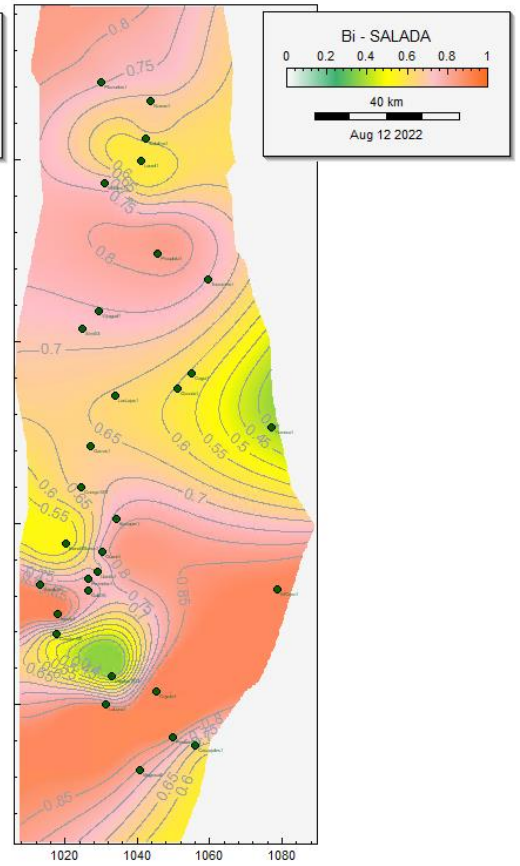
PHIO (%)



PHIE (%)



VClay (%)



Brittleness Index (fraction)

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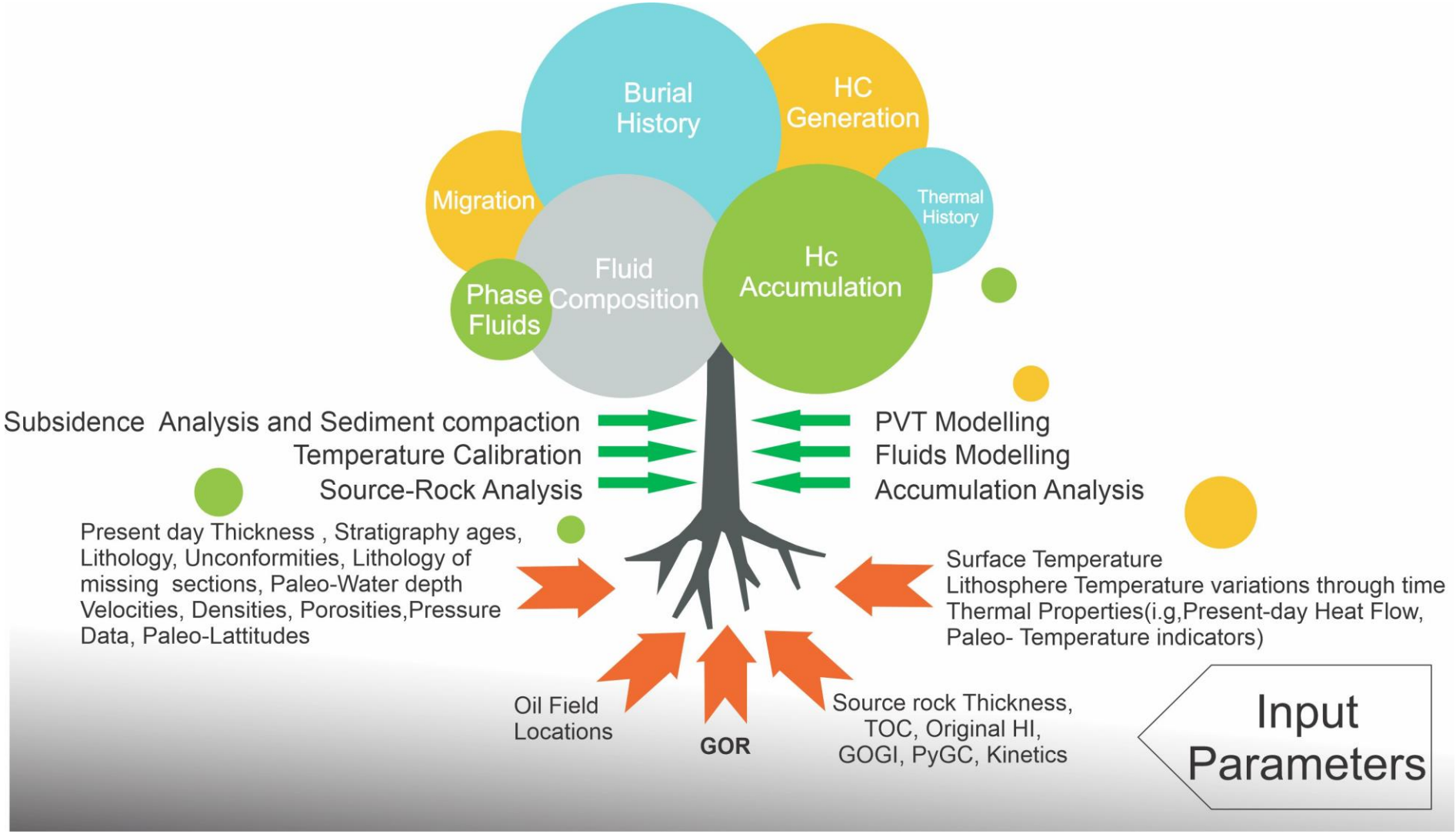
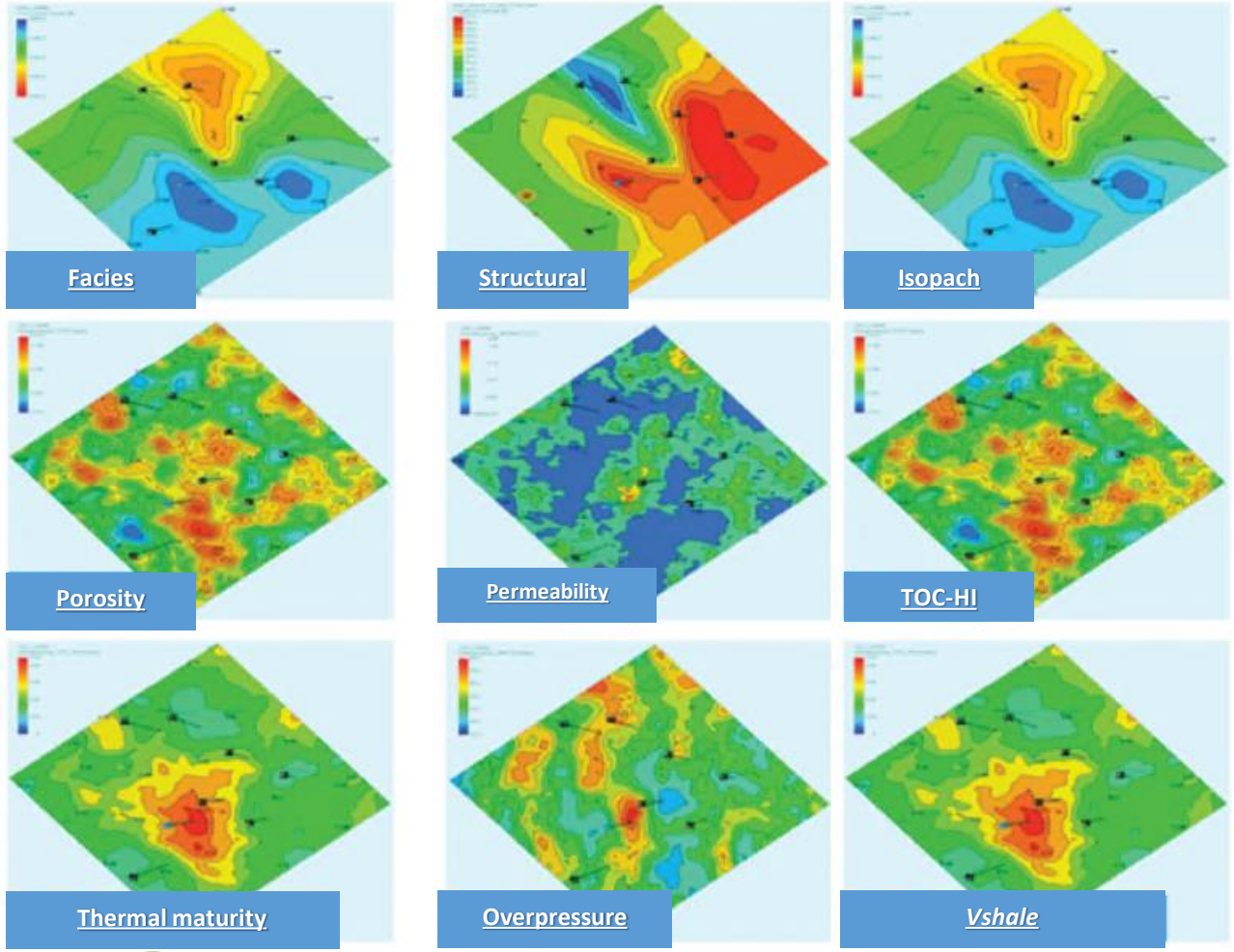
Petroleum Systems Analysis - Methodology



Petroleum Systems Analysis - Methodology



Analysis of three Upper Cretaceous rocks (so-called “La Luna Formation”): Salada, Pujamana and Galembo-La Renta formations

Twelve input maps for each source rock

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Petroleum Systems Analysis – 1D Calibration

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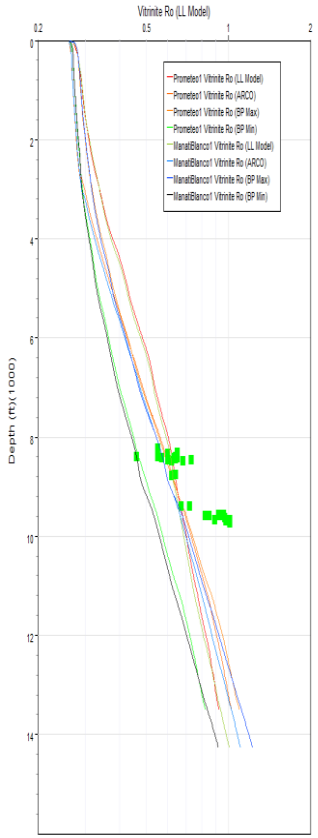

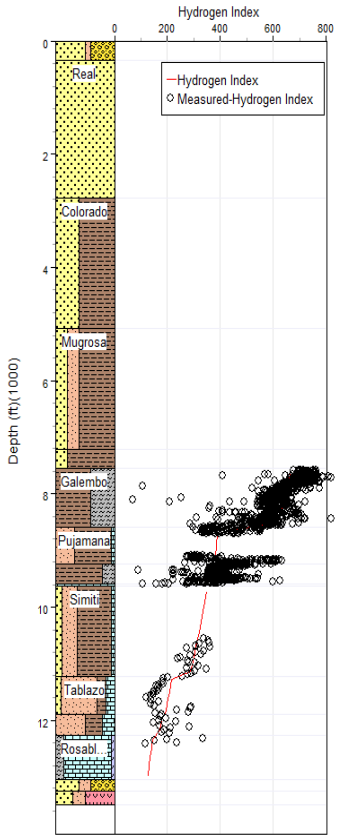

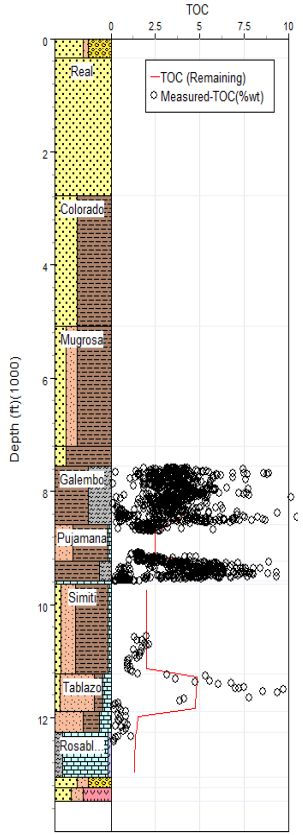

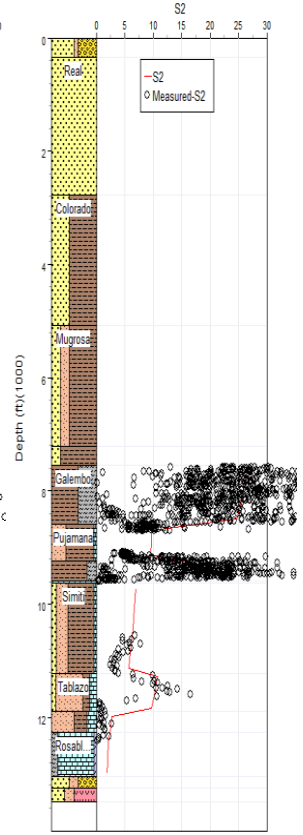

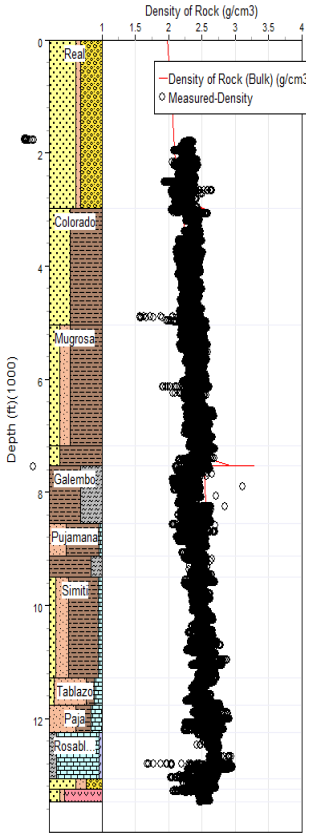

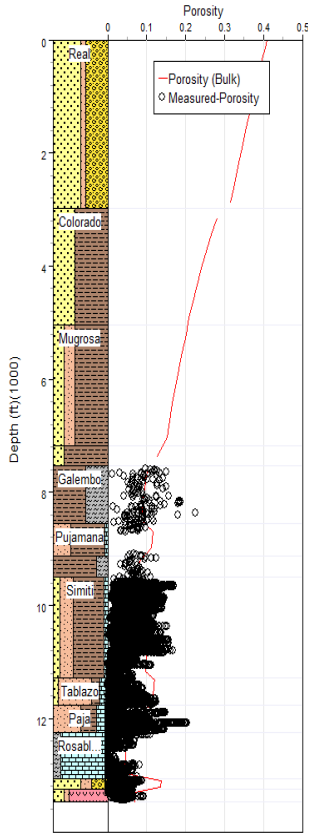

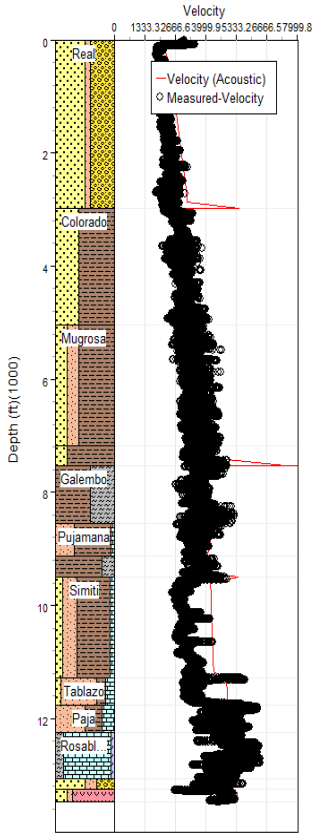

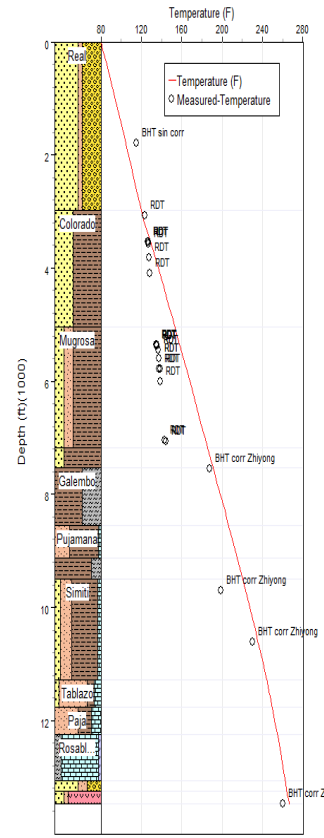

31 wells included in Petroleum Systems Analysis

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Petroleum Systems Analysis – 3D Model Calibration

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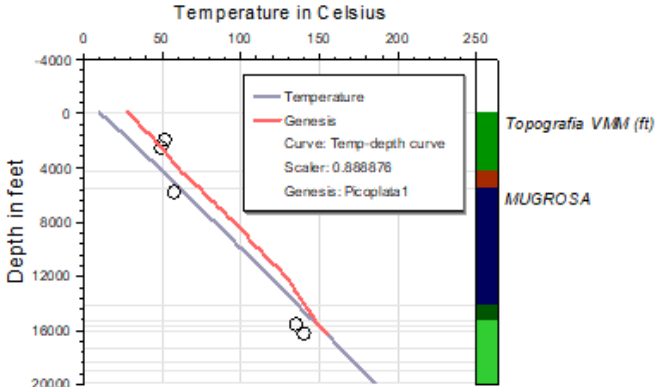
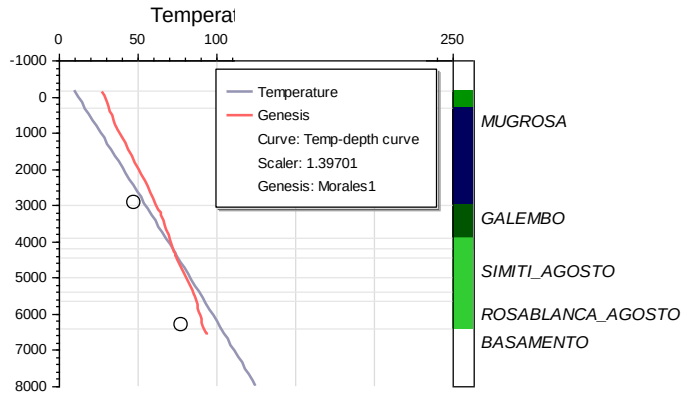
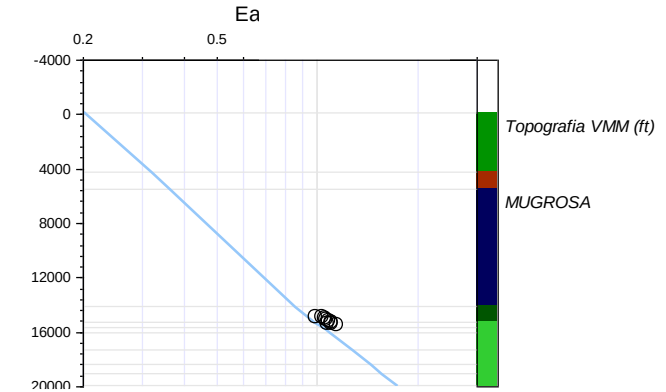
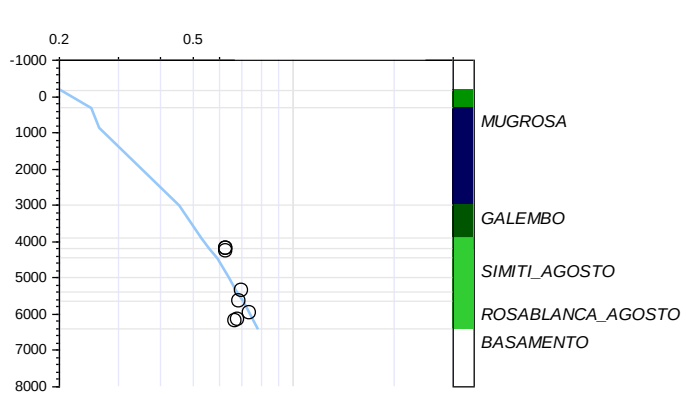
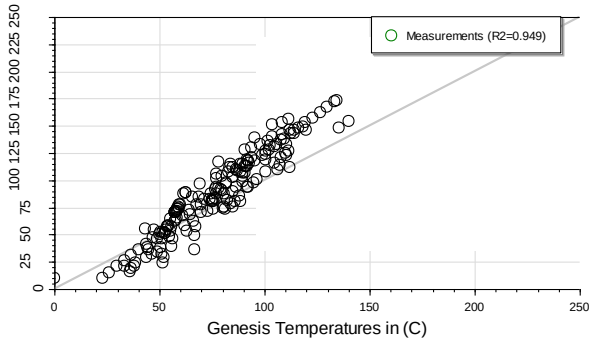




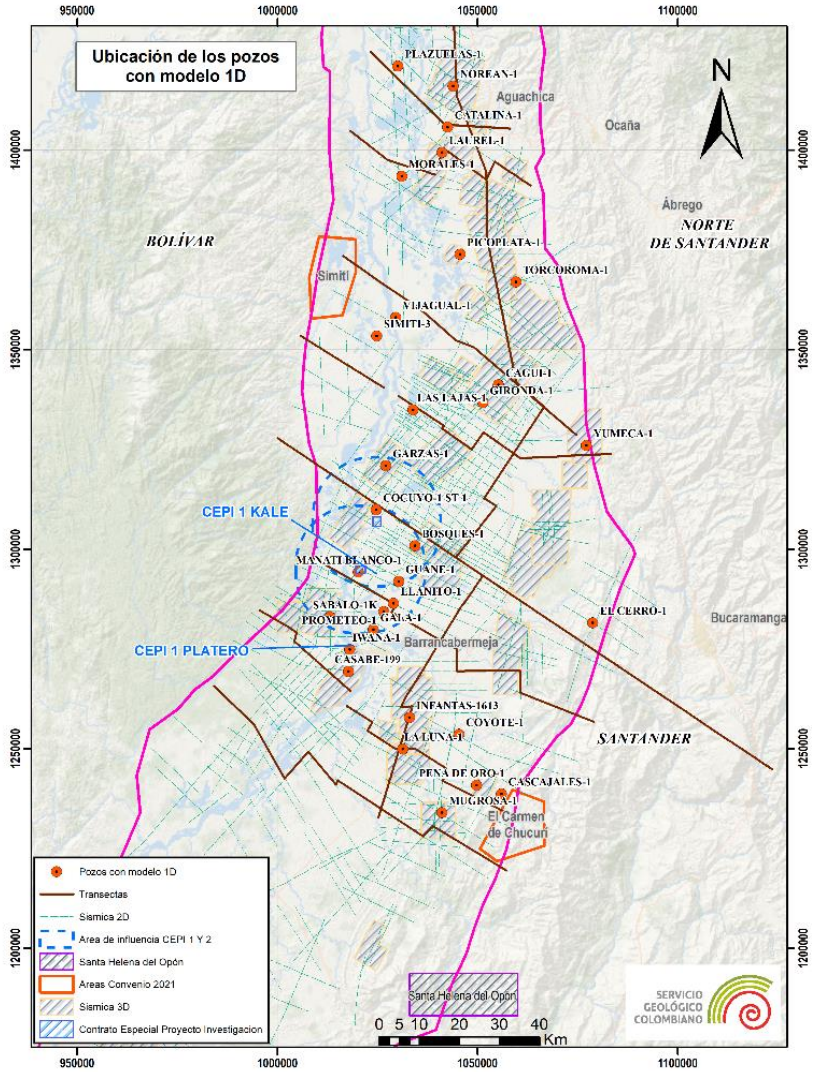




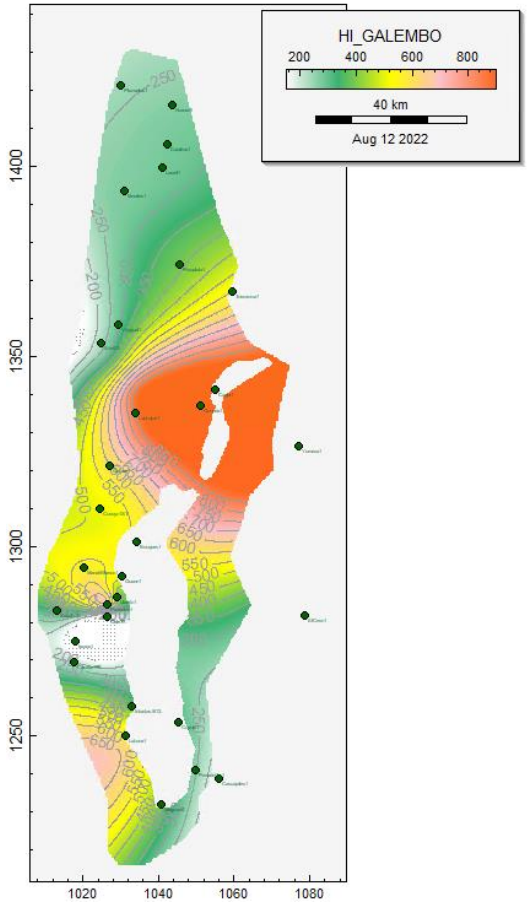


Strong correlation with measured data and 1D models

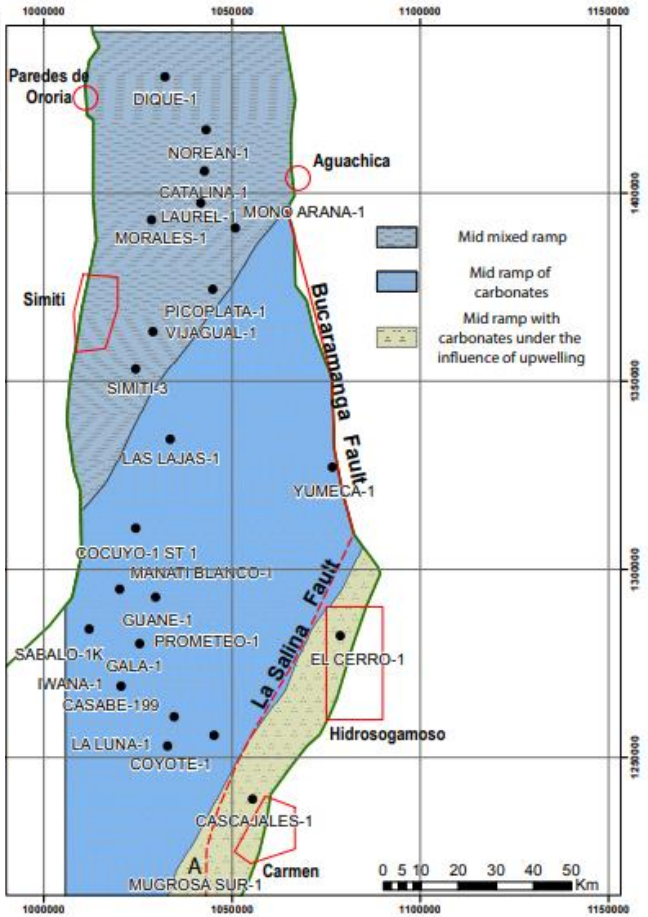
31 wells-1D models along basin (red dots)



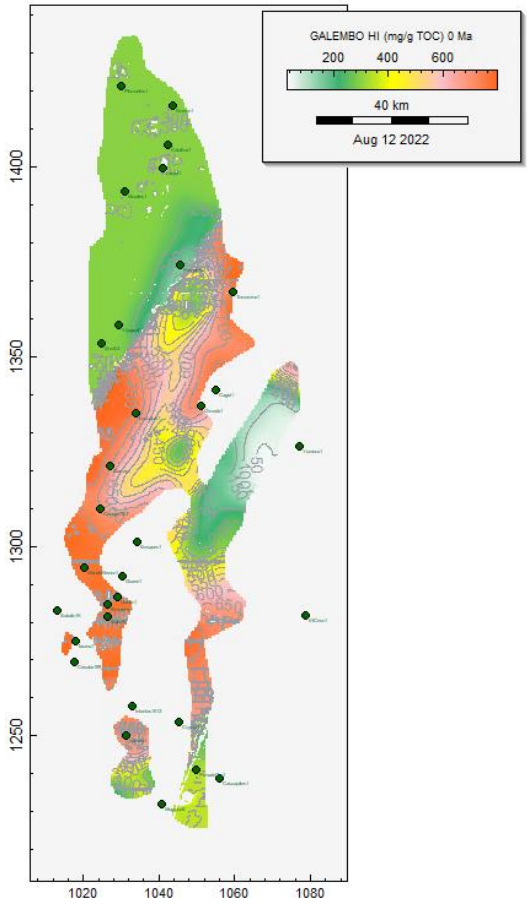
Petroleum Systems Analysis – 3D Model Calibration



Well data map



Paleo-facies map



3D model map

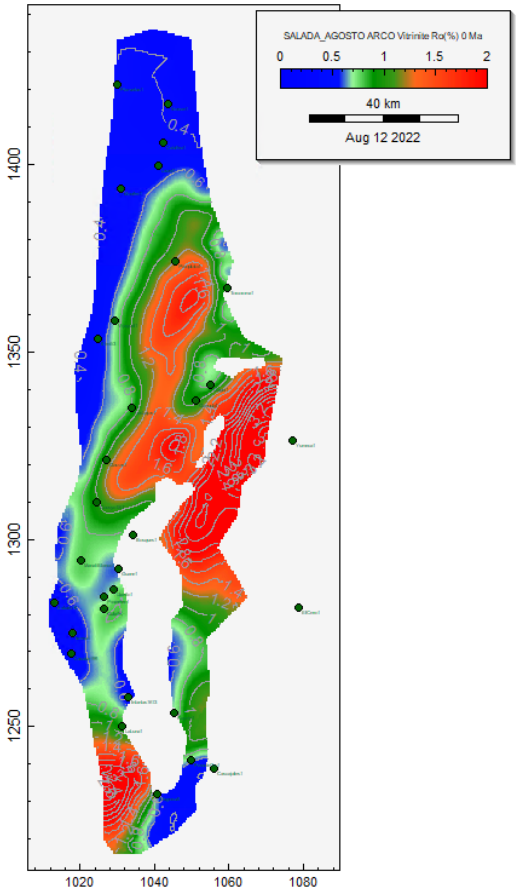
Cross validation with lab measurements, paleo-facies, petrophysics, isopach, structural and other maps (brittleness, TOC, Ro, etc.).

Analysis for the Salada, Pujamana, Galembo-La Renta formations.

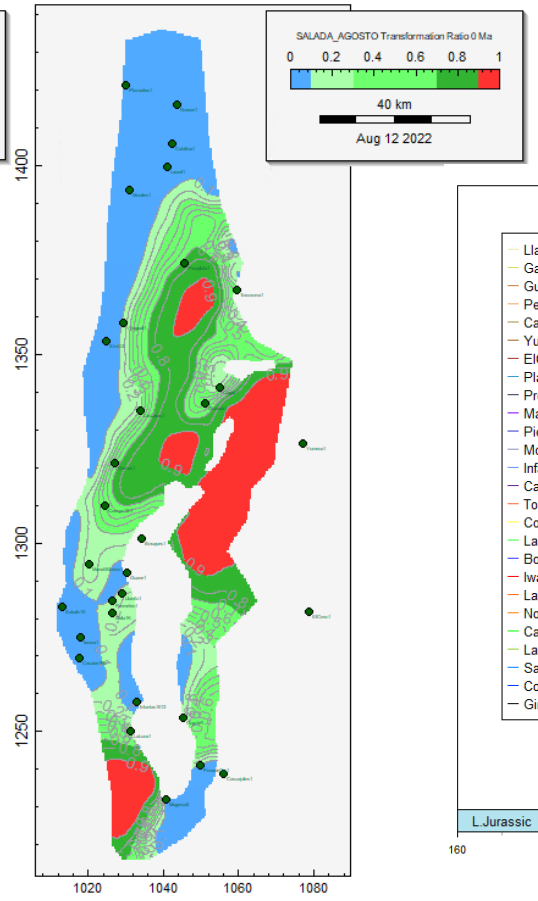
3D model maps considers geologic parameters as basin geometry, depth and compaction than maps from well data and contour gridding.

Petroleum Systems Analysis – Results

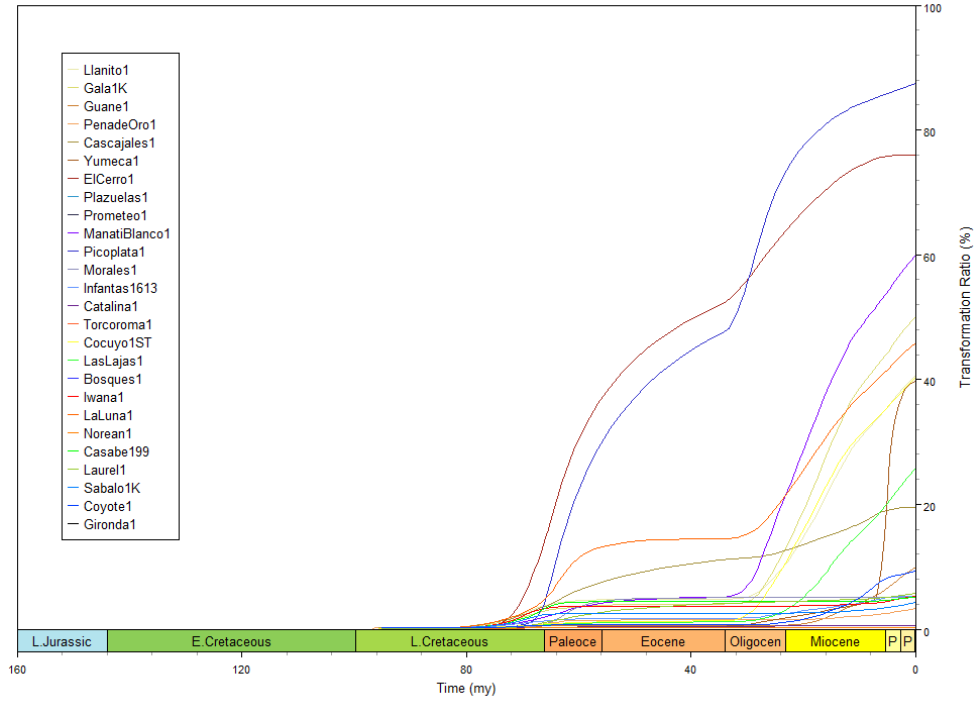
Thermal maturity and transformation ratio from 3D modelling



Thermal maturity from Ro (%)



Transformation ratio (%)



Transformation ratio (%) from wells data and 1D modelling

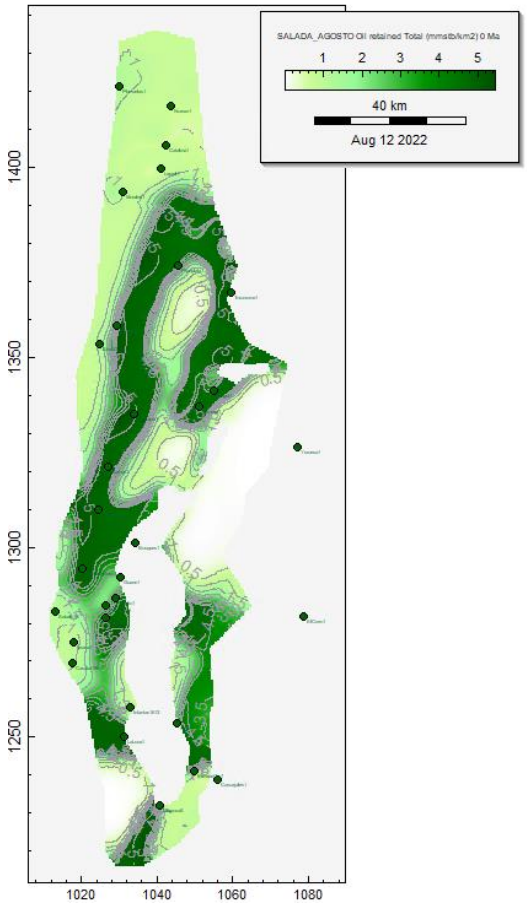
Analysis for the Salada, Pujamana and Galembo-La Renta formations.

Wells data and 1D modelling reveals no higher TR values than 90%. For example, Picoplata-1 reached 87% of transformation ratio in the Salada Formation.

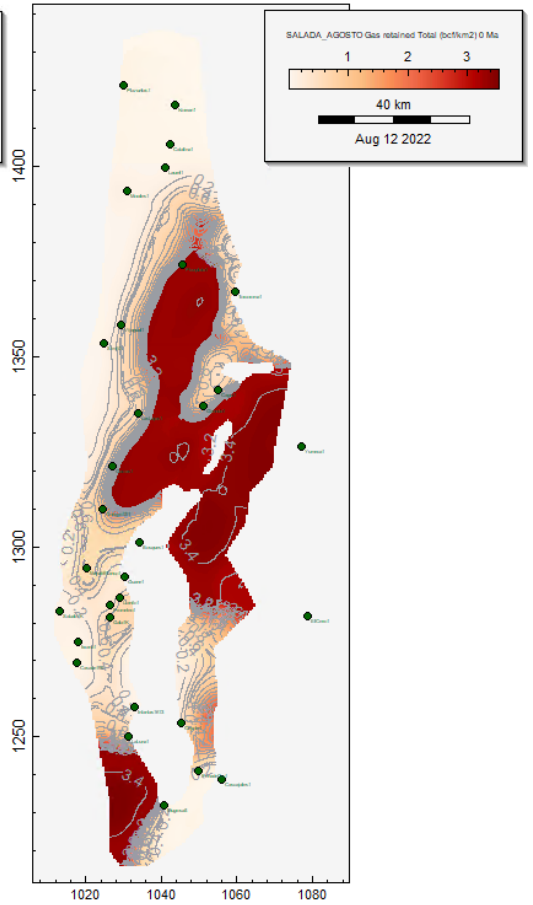
Most of drilled wells in the basin, were drilled in structural high areas.

Petroleum Systems Analysis – Results

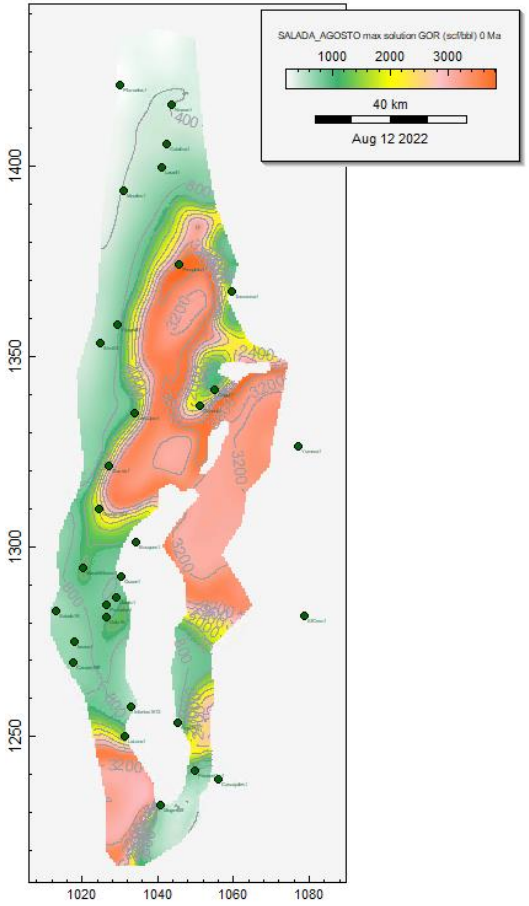
Gas-oil ratio (GOR) from 3D modelling



Retained oil (mmstb/km2)



Retained gas (bcf/km2)



Gas-Oil Ratio (scf/bbl)

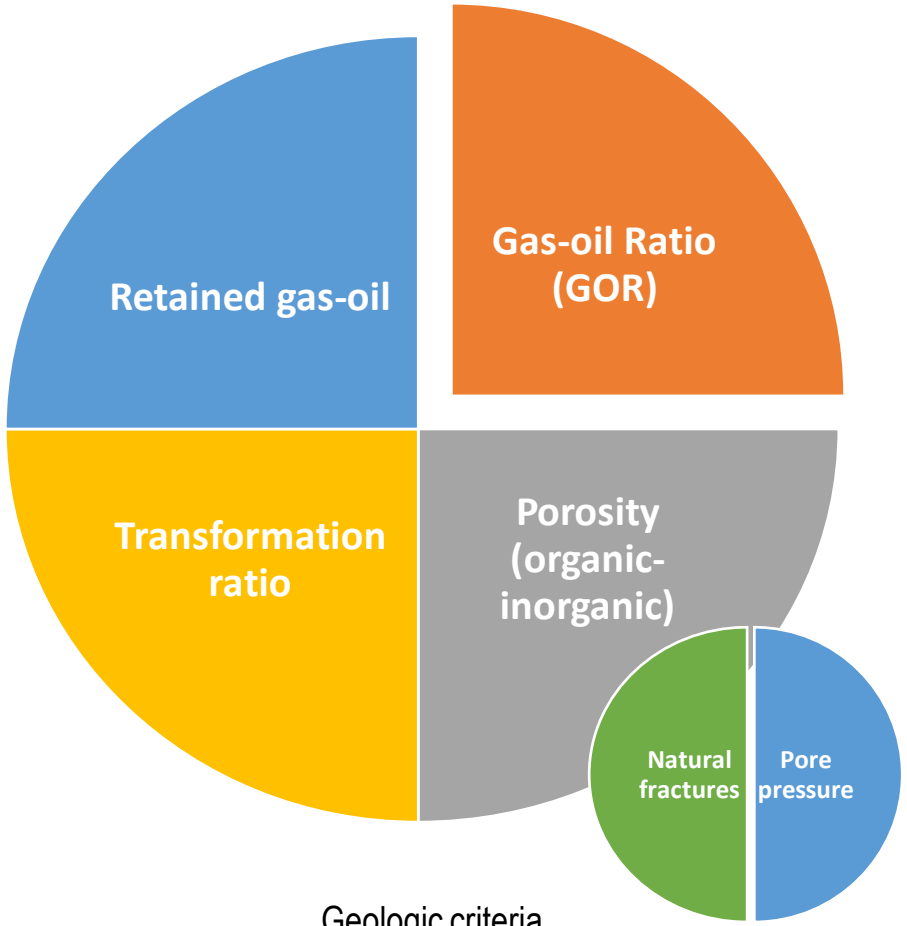
Analysis for the Salada, Pujamana and Galembo-La Renta formations.

GOR also indicates that a solution gas cap is the drive mechanism for producing liquid hydrocarbons

Usually, GOR ≥ 1.000 considered attractive in several basins (e.g., Western Gulf Basin – Eagle Ford Shale)

Petroleum Systems Analysis – Results

Sweet spot definition and geologic criteria



Geologic criteria

Criteria	Low (0)	Fair (0.5)	Good (1)
Porosity (%)	≤ 2%	2% - 5%	≥ 5%
Transformation ratio (fraction)	≤ 0.2	0.2 - 0.5	≥ 0.5
Gas-Oil Ratio - GOR (scf/bbl)	≤ 1000	≥ 1000	
Retained oil (mmstb/km2)	≤ 1.0	1.0 - 5.0	≥ 5.0
Retained gas (bcf/km2)	≤ 0.5	≥ 0.5	

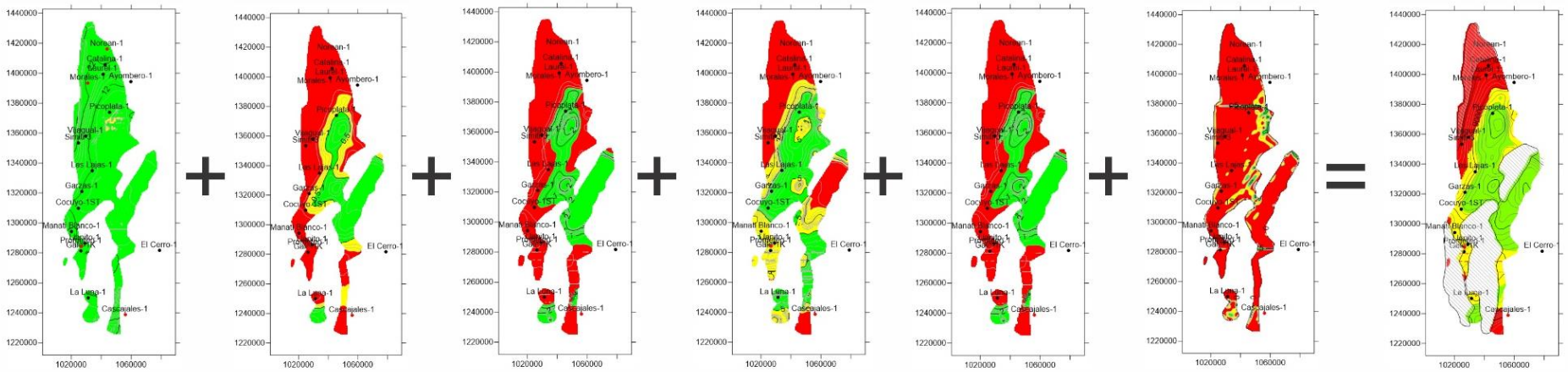
Sweet spot cut-parameters

Analysis for the Salada, Pujamana and Galembo-La Renta formations.

Sweet spots depend o geology and basin conditions. Several geologic criteria evaluated and do not have implications in sweet spot definition (e.g., mineralogic brittleness, thickness)

Petroleum Systems Analysis – Results

Sweet spot definition and geologic criteria



PHIE (%) + Transformation ratio (fraction) + GOR (scf/bbl) + Retained oil (%) + Retained gas (%) + Curvature prediction (optional) = **Sweet spot map**

Analysis for the Salada, Pujamana and Galembo-La Renta formations.

Sweet spots depend on geology and basin conditions. Several geologic criteria evaluated and do not have implications in sweet spot definition (e.g., mineralogic brittleness, thickness).

Curvature prediction: screen areas with high or low natural fractures probability

Sweet spots also help in conventional oil and gas play definition (e.g., tight sands, naturally fractured reservoirs)

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Petroleum Systems Analysis – Results

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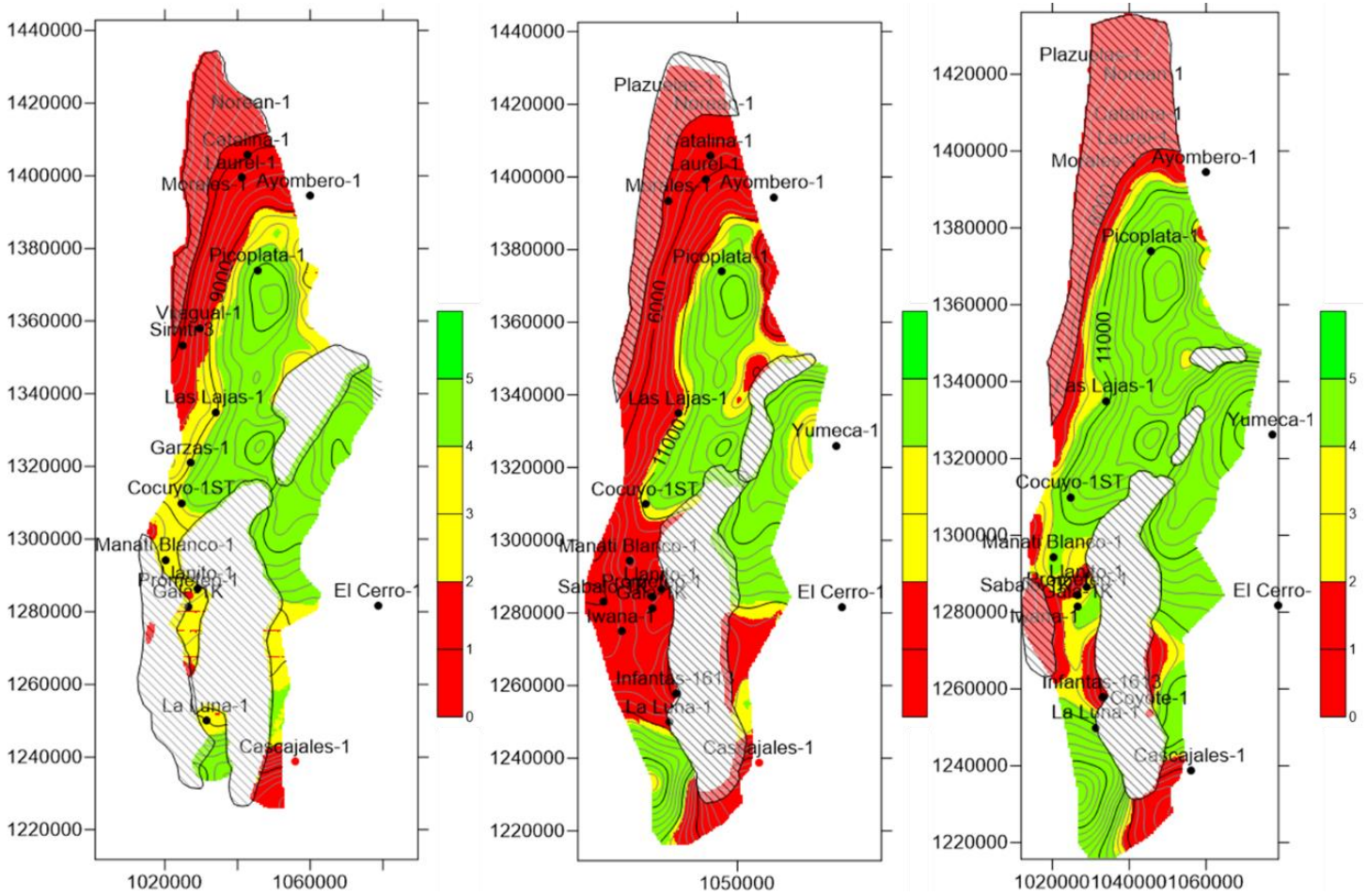
Sweet spot maps and resources estimation



Galembo-La Renta | Pujamana | Salada

	Salada	Pujamana	Galembo-La Renta	Total
Gas Retained Total (unrisked)	**10 TCF**	**5,8 TCF**	**4,8 TCF**	**20,6 TCF**
Oil Retained Total (unrisked)	**15,5 Bbls**	**8,8 Bbls**	**20,5 Bbls**	**44,8 Bbls**
Gas Total Retained*	**1,5 TCF**	**0,87 TCF**	**0,72 TCF**	**3,09 TCF**
Oil Total Retained*	**2,32 Bbls**	**1,32 Bbls**	**3,07 Bbls**	**6,71 Bbls**

**After 15% RF*