

Assessing the Hydrocarbon Exploration Potential of the Jurassic Cuyo Goup, SW Neuquén Basin: Through Outcrop Analog Studies*

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Abstract

The Laguna Blanca Block, located in the SW of Argentina's Neuquén basin, is a poorly explored region in a highly mature basin. Since the early 1950s, only six wells have been drilled in an area exceeding 5750 km². Historical exploration has been almost exclusively focused on structural plays, related to Jurassic inversion of Triassic-Early Jurassic half-grabens, and Upper Cretaceous and younger structures related to the Andean Orogeny. Sparse subsurface data, including the wells and a widely spaced 2D seismic mesh, has precluded the identification of alternative plays, especially those associated with stratigraphic traps, which have been successful elsewhere in the basin. Therefore, multidisciplinary study of analogous Jurassic Cuyo Group sediments in La Jardinera outcrops, immediately west of Laguna Blanca Block, provides additional insight into subsurface geology. The Cuyo Group consists of fluvial sandstones and conglomerates (Challaco Formation); shallow marine deltaic to shelf sandstones (Lajas Formation); and deepwater shales, slope channel and basin floor fan sandstones (Los Molles Formation). The marine Los Molles shales are a good potential source rock; deepwater (Los Molles) and shelfal (Lajas) sandstones represent potential reservoirs. Facies descriptions, interpretation of sedimentological measured sections, photomosaics, and drone imagery helped to identify and define specific depositional environments, the lateral extent and geometries of sand bodies, and general net-to-gross ratios. Three-dimensional paleo-environmental models of the Lajas-Molles system help to identify possible stratigraphic plays in the Cuyo Group. Additional petrophysical, petrographic, and geochemical studies further characterize the potential petroleum system.

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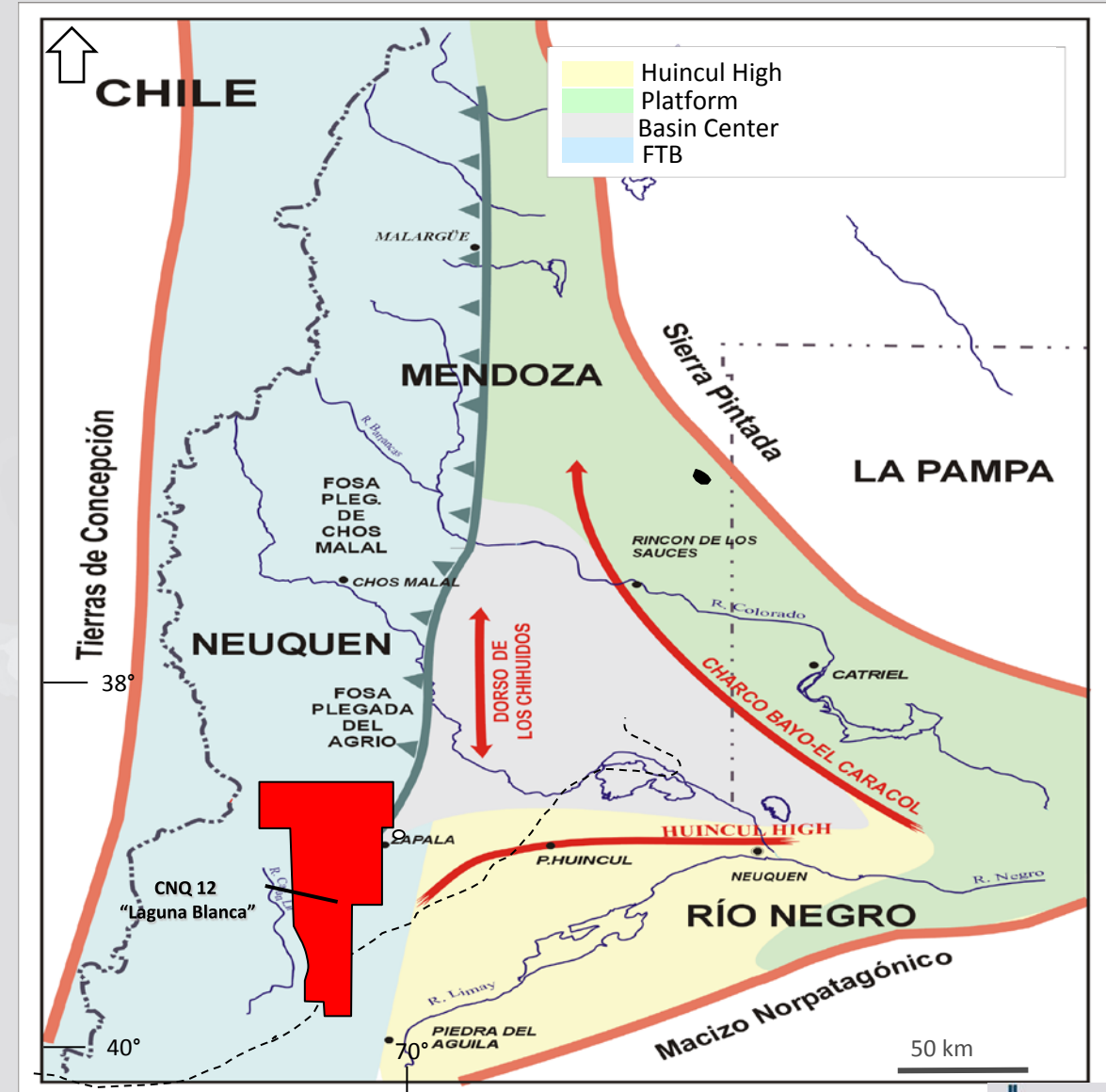


- The area is located close to the Southern border of Neuquen embayment

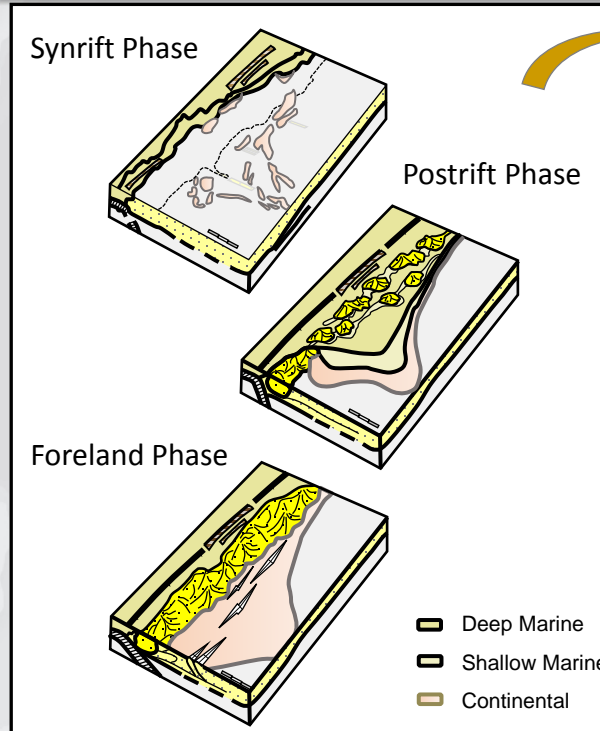


- The objective of this work is reassessing the hydrocarbon potential of an underexplored area in the Neuquen Basin:

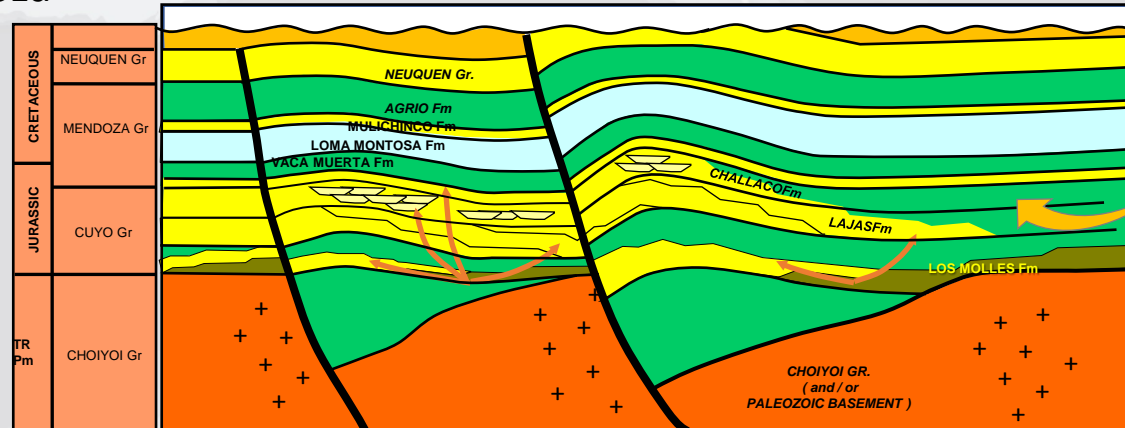
- Done through definition of new potential plays both in outcrop and subsurface
- Complemented with thoughtful revision for each of the petroleum system elements by means of field work, sample collection and lab studies



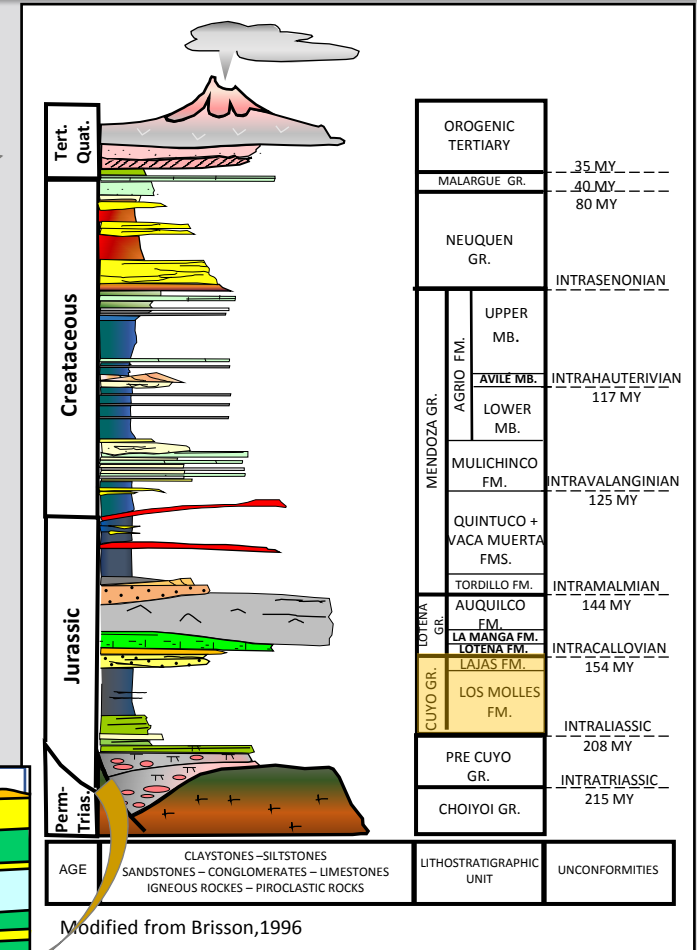
- Different structural styles responding to three superimposed basins stages
- All of these stages can be identified on the Block stratigraphy
- Petroleum system given by Pleinsbachian Los Molles Fm. as source rock, feeding reservoirs within Cuyo Gr. and the Mendoza Gr.

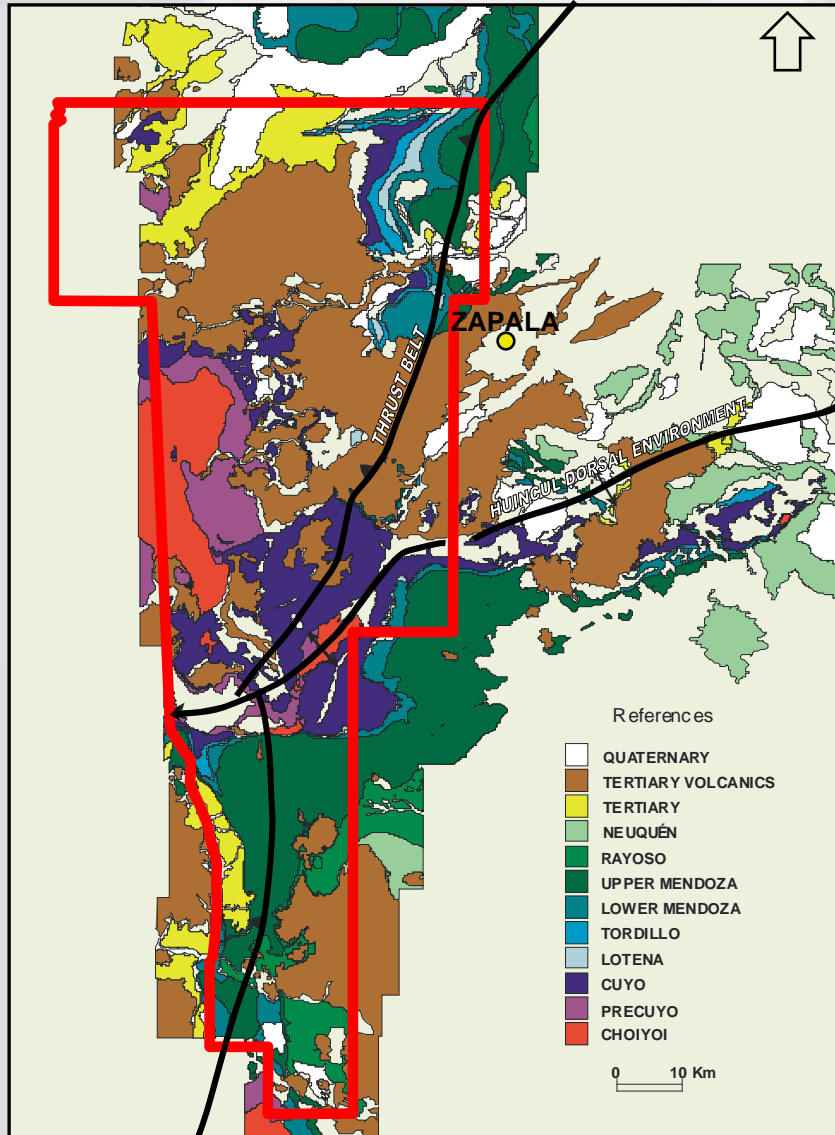


Modified from Howell, et al., 2005



Modified from Legarreta et al., 2005



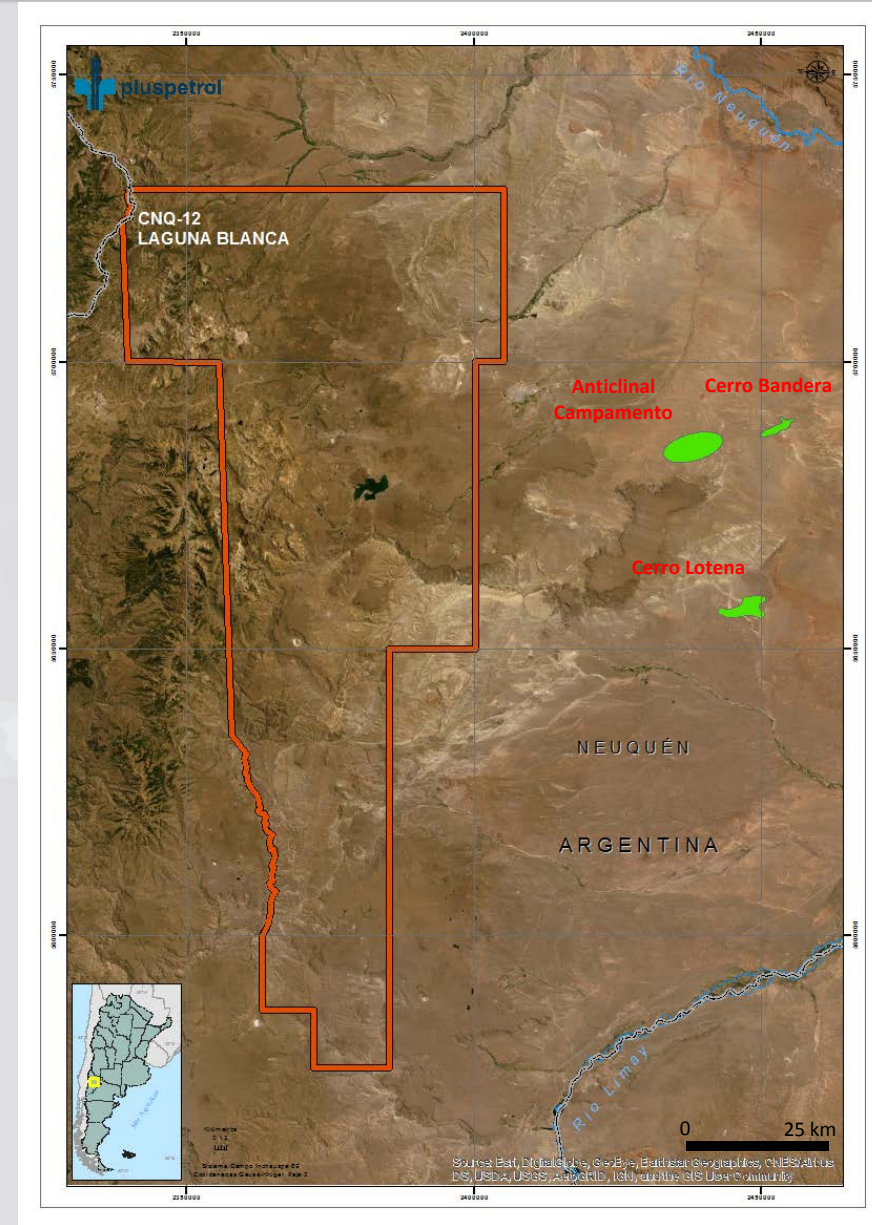


- Main structural features within the Laguna Blanca Block given by convergence of the Huincul high with the folded thrusts belt
- Central & Northern portion of Laguna Blanca Block shows E-W oriented anticline (associated with Alenian inversion of preexisting structures)
- Southern area of Laguna Blanca Block characterized by N-S oriented anticlines given by Andean inversion of preexisting structures

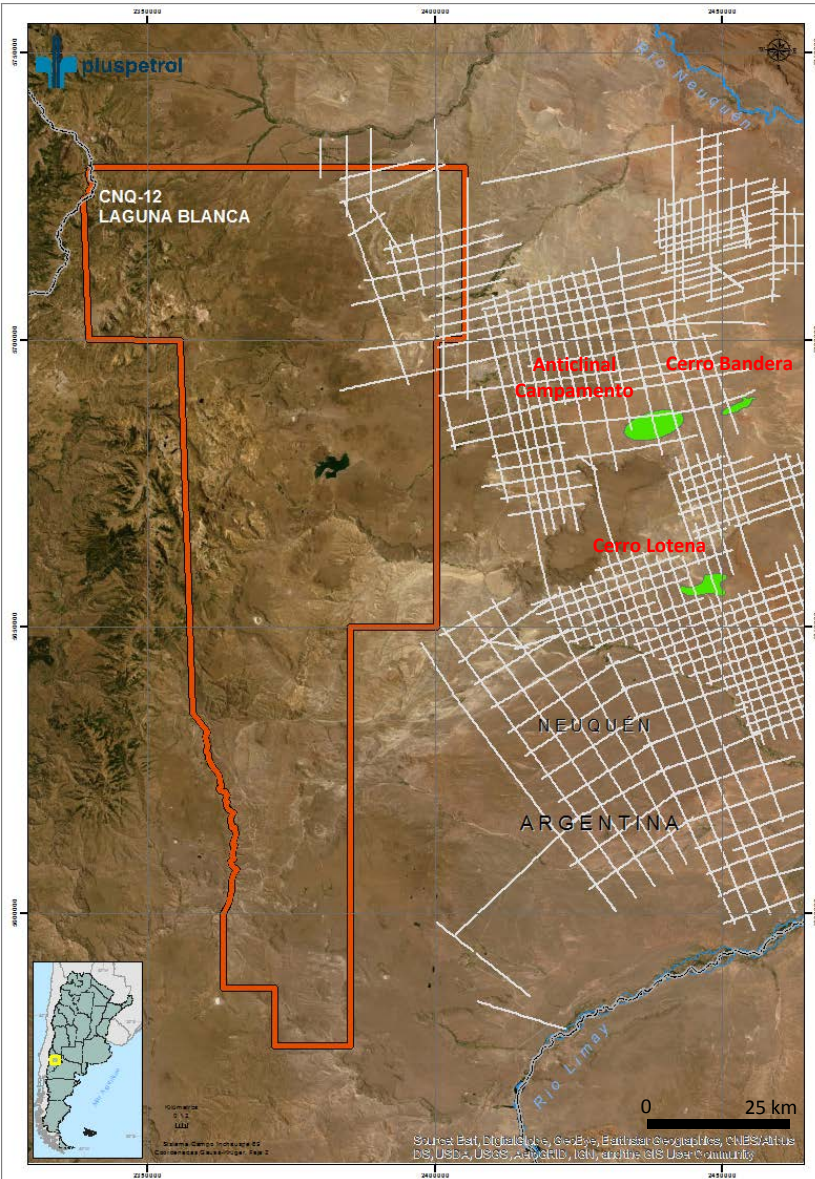
Exploration History & Available Data



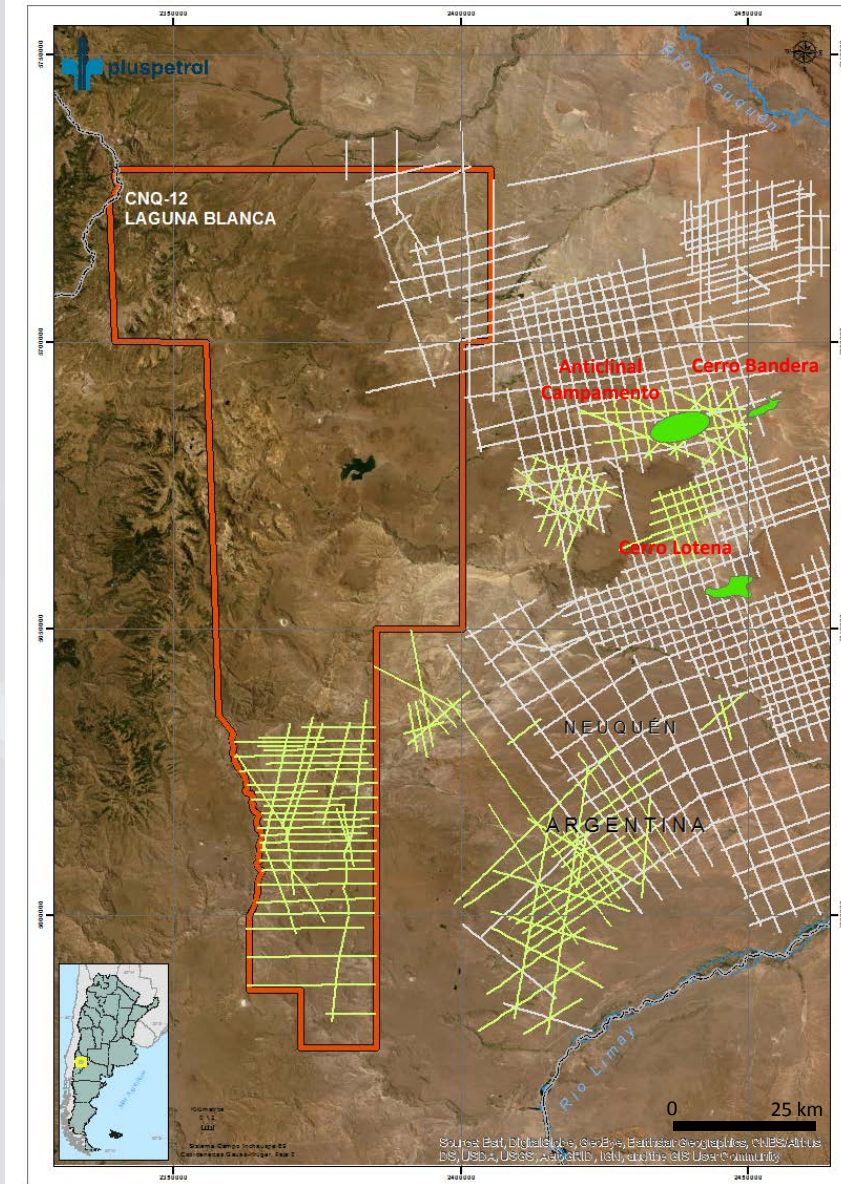
- Series at Cerro Bandera, Cerro Lotena & Anticlinal
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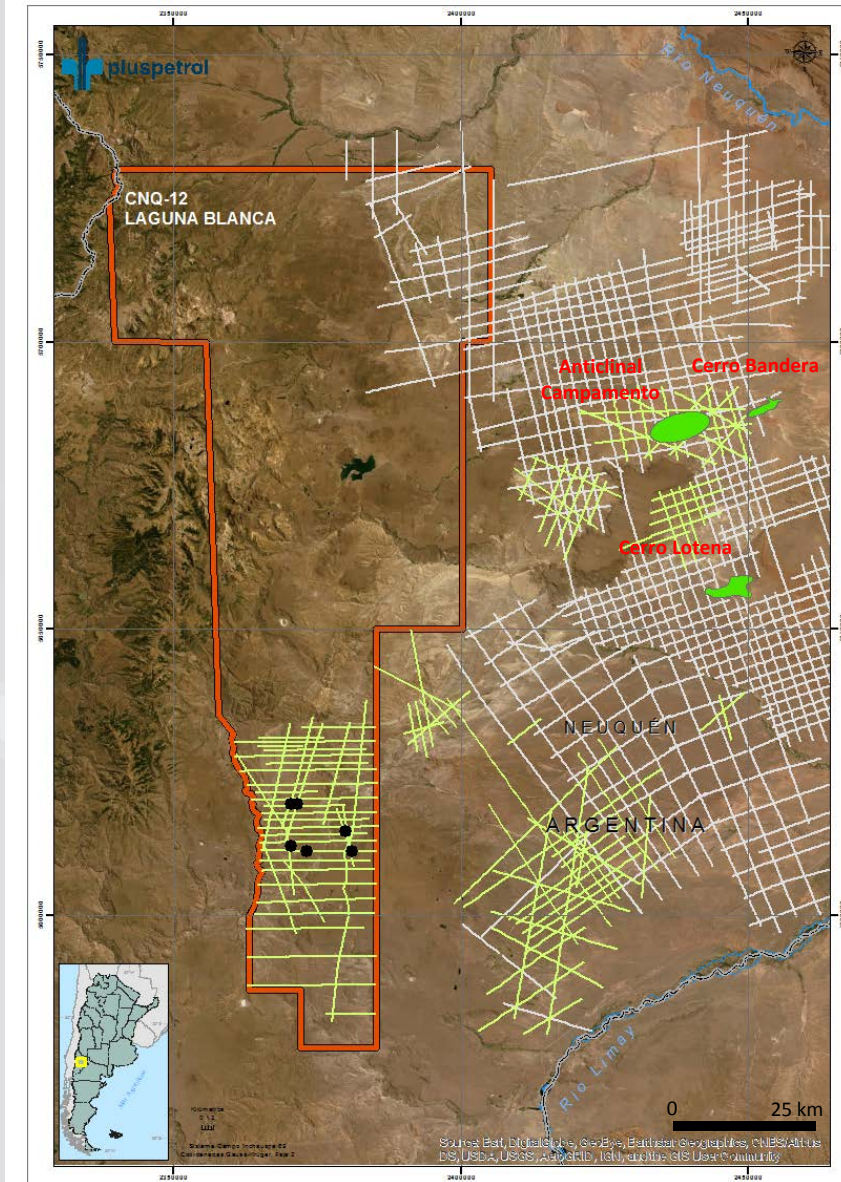
- s at Cerro Bandera, Cerro Lotena & Anticlinal
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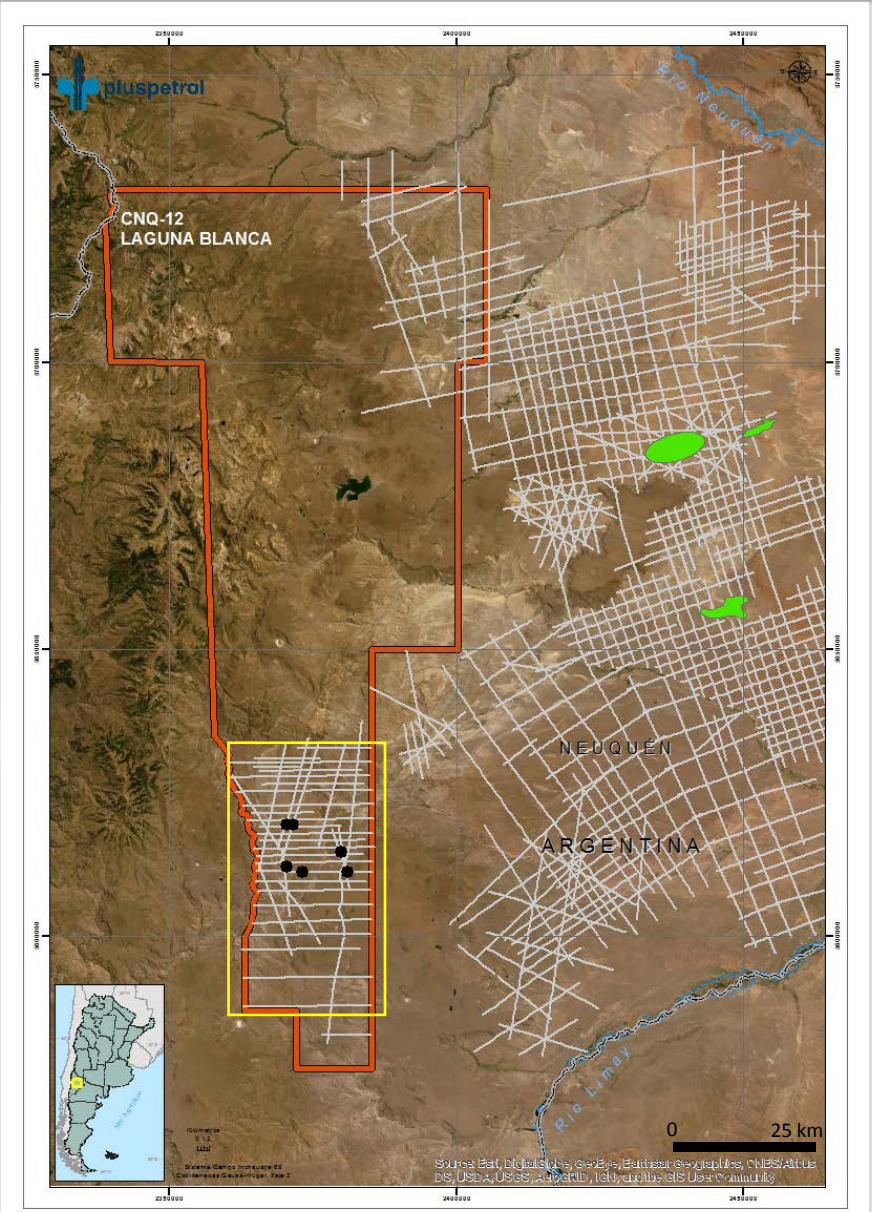


- Discoveries at Cerro Bandera, Cerro Lotena & Anticlinal Campamento
- YPF acquired 2D seismic data with a relatively open exploration mesh (1970-80)
- Several seismic programs complemented existing seismic data (Picun Leufu consortium, Astra and Petrolera San Jorge).



- Discoveries at Cerro Bandera, Cerro Lotena & Anticlinal Campamento
- YPF acquired 2D seismic data with a relatively open exploration mesh (1970-80)
- Several seismic programs complemented existing seismic data (Picun Leufu consortium, Astra and Petrolera San Jorge).
- Within the Laguna Blanca Block 6 wells were drilled based on surface geology (5 YPF & 1 San Jorge)





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Outcrop Studies & Play Definition



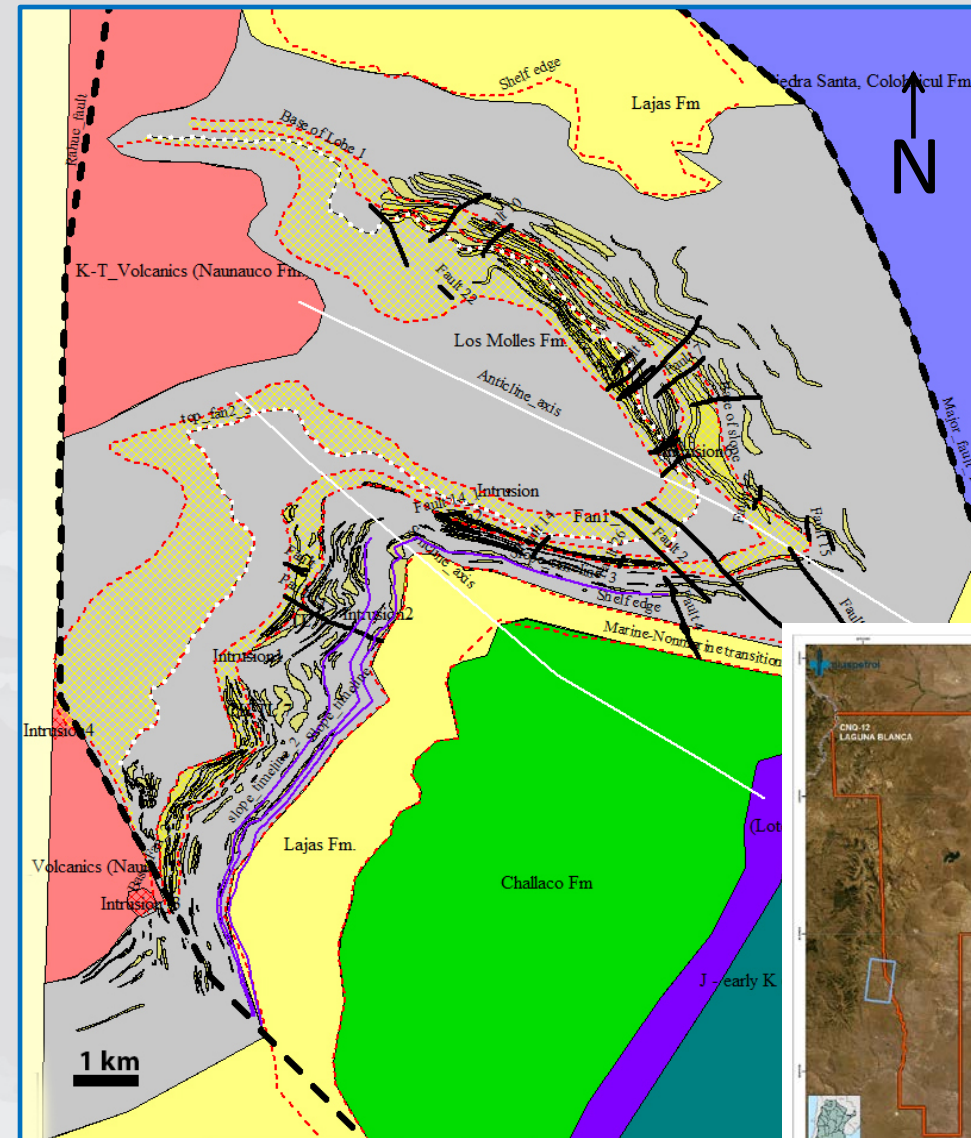
- World-class, Lower-Middle Jurassic 3-D outcrops at La Jardinera



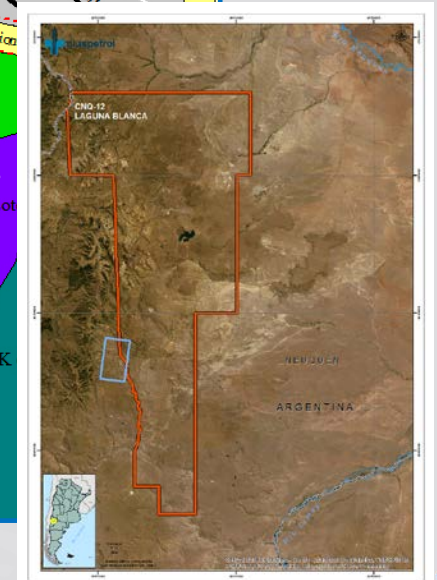
- Basic 3-D outcrops
- Conditions allow unusual shelf margin in
- Geological systems at
- Relationship between environmental



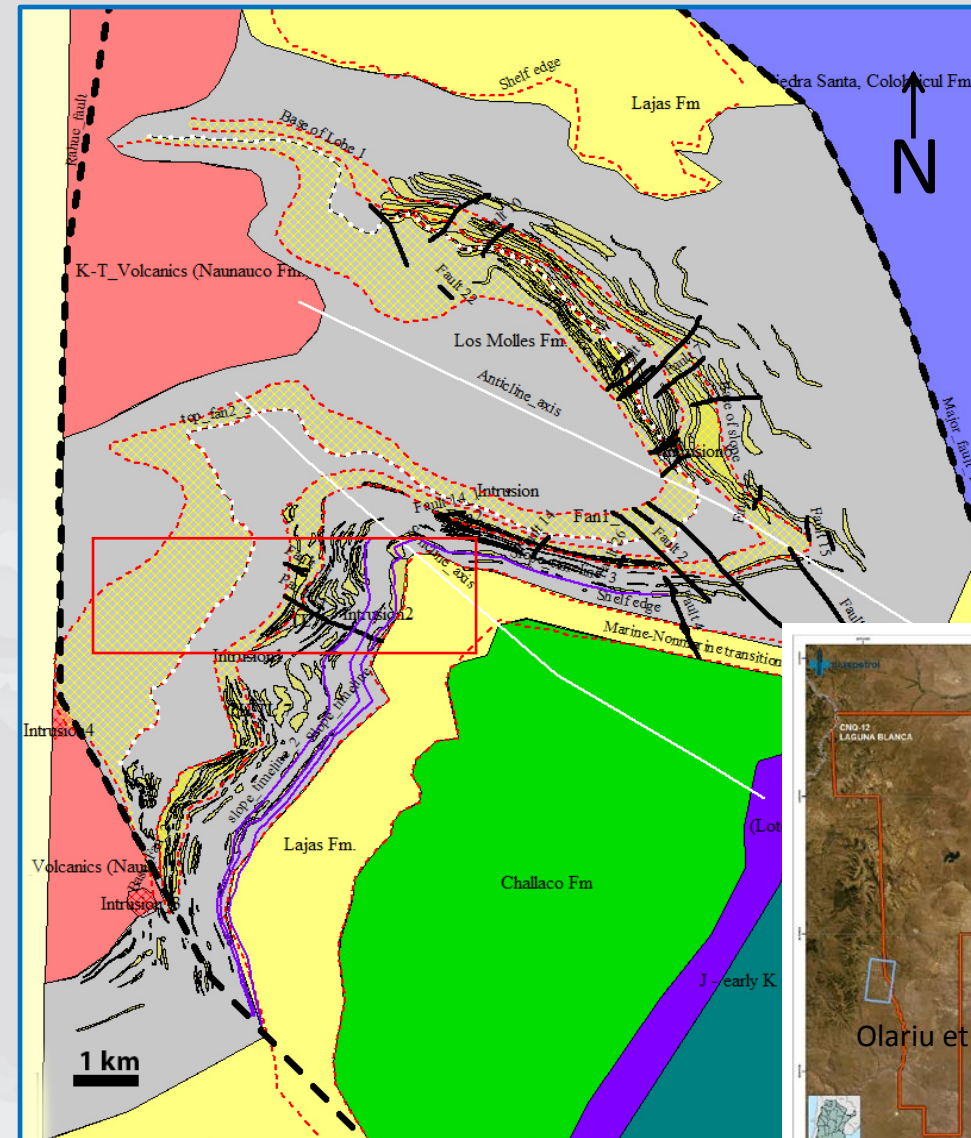
- The entire succession comprises large scale clinoforms that were folded post depositionally
- Outcrops allow the description of environments from the “distal” basin floor muds and turbidites to the proximal fluvial deposits



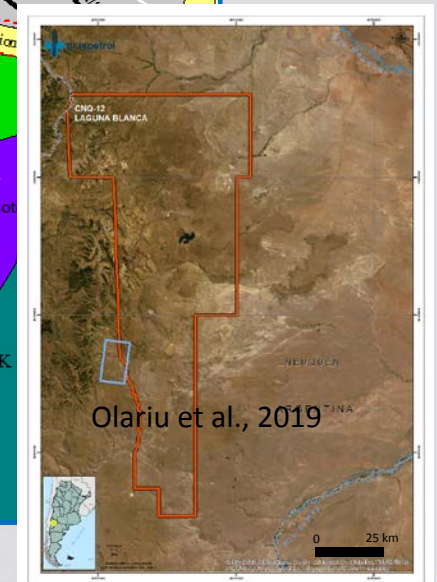
Olariu et al., 2019 modified from Paim et al., 2008



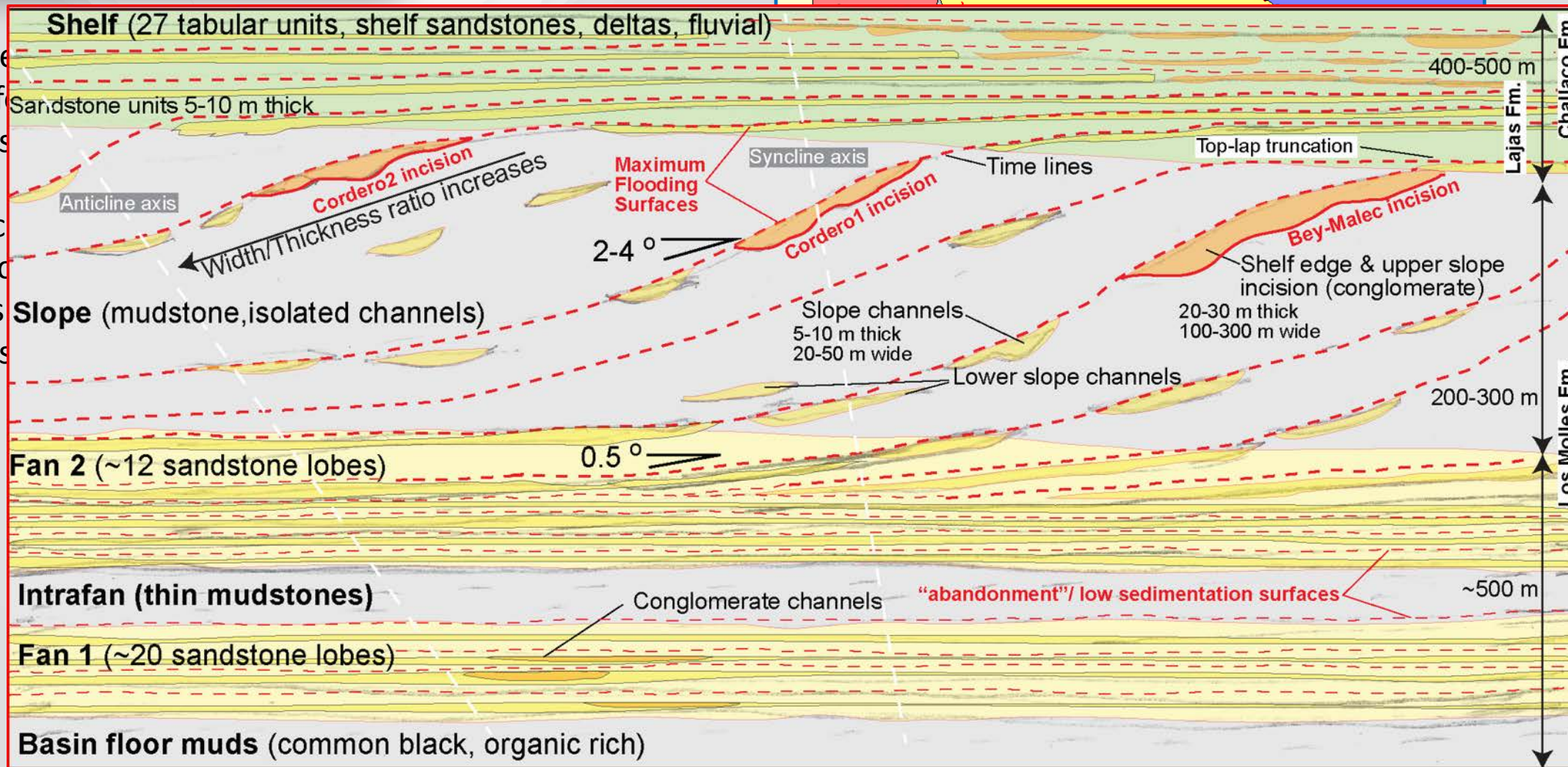
- The entire succession comprises large scale clinoforms that were folded post depositionally
- Outcrops allow the description of environments from the “distal” basin floor muds and turbidites to the proximal fluvial deposits
- Architecture for the Cuyo Gr. showing vertical and lateral transition from shelf to basin floor can be studied



Olariu et al., 2019 modified from Paim et al., 2008

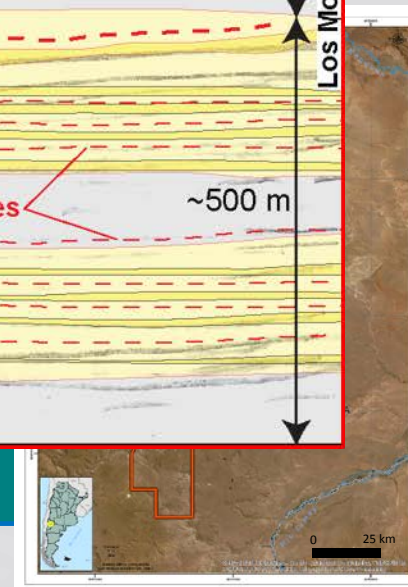


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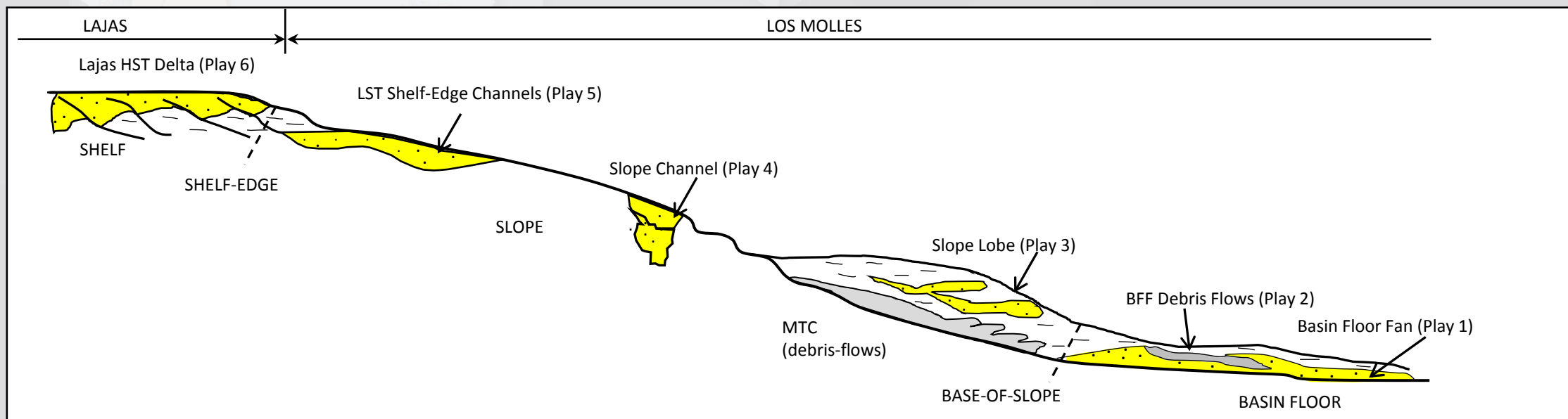


- Architecture for the Cuyo Gr. showing vertical and lateral transition from shelf to basin floor can be studied

Olariu et al., 2019 modified from Paim et al., 2008



- Six stratigraphic plays with pinch out or truncation traps defined based on field observations (if deformed becoming part of syncline-anticline structures could be structural plays as well)
 1. Los Molles BFF
 2. Los Molles BFF truncated by Debris Flows
 3. Los Molles Slope Fans
 4. Los Molles Slope Channels
 5. Los Molles Shelf Edge Channels
 6. Lajas Platform Deltas
- Detailed studies were done on each (extension, thickness, NTG & lateral relations)

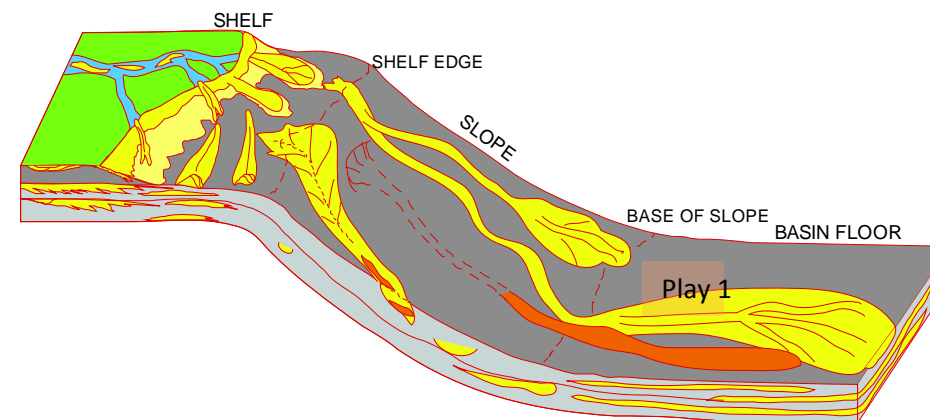
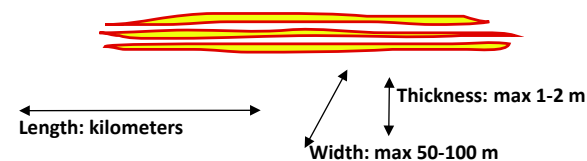


• PLAY 1: BASIN-FLOOR FANS (STRATIGRAPHIC TRAPS)

- Everywhere where sandstone basin floor fans are present
- Multiple (10-20) units, m to 10' of m thick amalgamated sandstones, kilometers wide (depositional strike) and kilometers long (depositional dip)
- Regionally extended transgressive muds m to 10' of m thick between individual units (seal type 1) or regionally extensive slope muds (seal type 2).
- Large area, recognizable on seismic
- Variable Φ - K properties along the same m thick unit or between stacked units

1

Basin Floor Fans



PLAYS 3/4: SLOPE LOBES /SLOPE CHANNELS (STRATIGRAPHIC TRAPS)

- 100s m apart in channels or “lobes”
- Low number of stacked units (1-4), m to 10s m thick usually non-amalgamated sandstones, 100s m wide (depositional strike) and km long (depositional dip)
- Slope mud might act as a seal in the landward part of the depositional system
- If connected to BBF might be relatively large
- Slope channels might be continuous all the way to the shelf

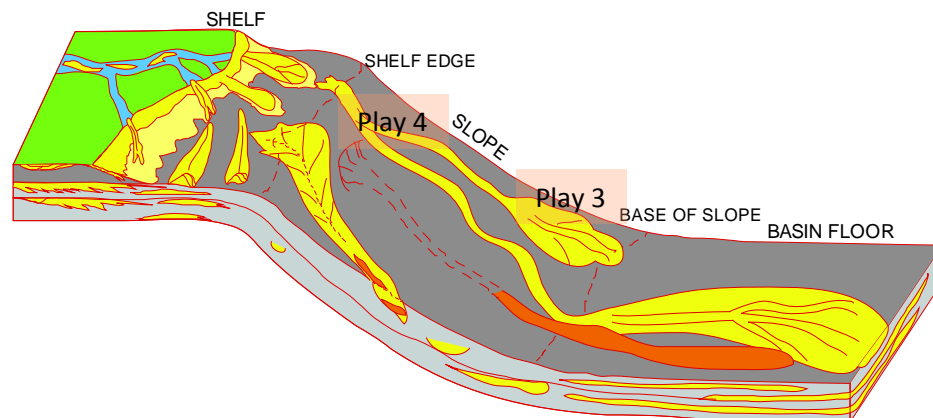
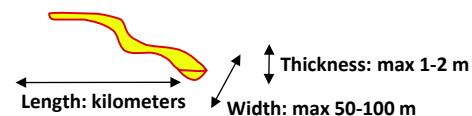
3

Slope Lobes



4

Slope Channels



Petroleum System Elements Studies



1- BASIC PETROPHYSICS (LCV)

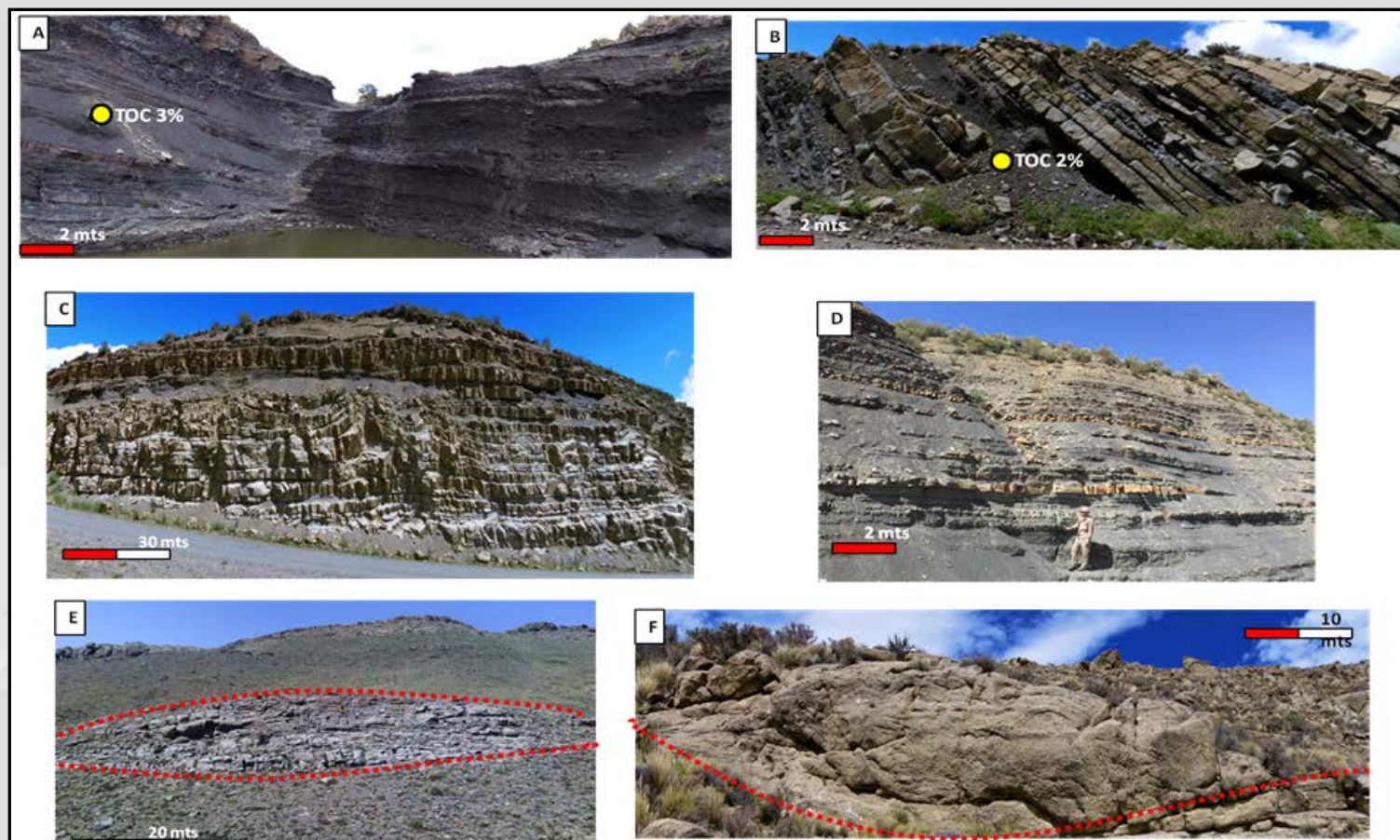
- ✓ Porosity & permeability

2- PETROGRAPHY (CIG-Conicet)

- ✓ Compositional analyses (thin section)
- ✓ X Ray Diffraction (mineralogical comp.)
- ✓ Electronic Microscopy (MEB)
- ✓ Diagenetic Trends

3- GEOCHEMESTRY (Geo Lab Sur)

- ✓ TOC and Pyrolysis
- ✓ Maturity and Kerogen visual analyses
- ✓ Vitrinite reflectance

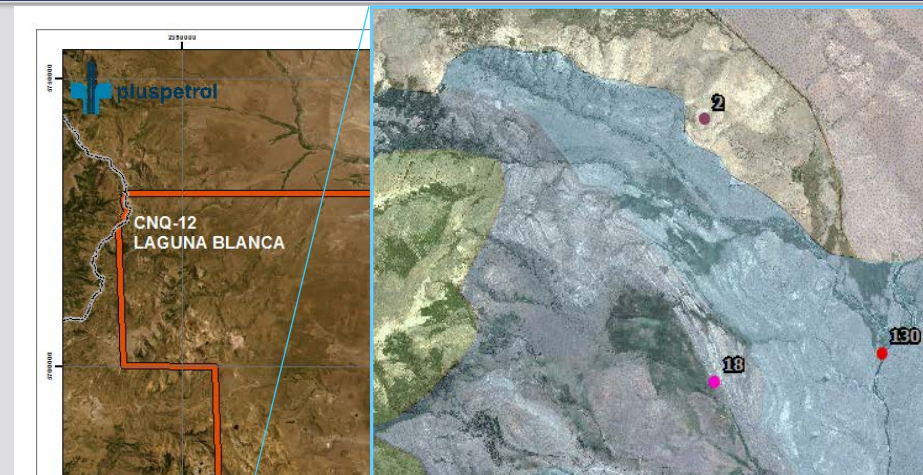


Outcrop pictures from the different paleoenvironmental settings for Cuyo Group in Arroyo La Jardinera area.

- A-Basin Plain-Dark grey shales
- B-Basin floor lobes
- C- Channel incision at the base of the slope
- D-Slope-heterolithic deposits
- E- Slope channel
- F- Channel in delta front facies

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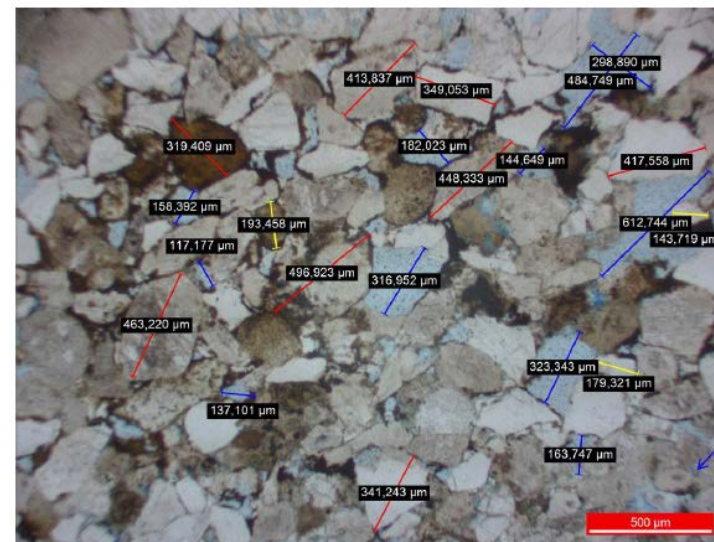
- Petrophysics analyses performed on all the potential subsurface analog reservoirs
- Average Porosity and Permeability values from outcrop samples were defined



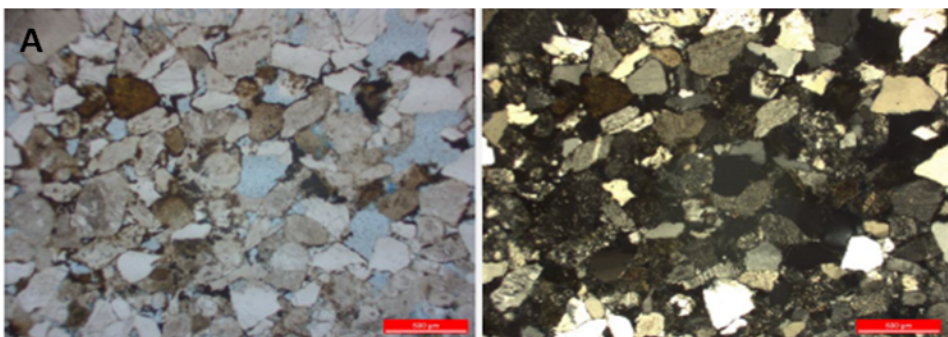
Statistical Analysis										
Reservoir	Phi Average (%)	Max	Min	Str. Dev.	Median	K Average (mD)	Max	Min	Str. Dev.	Median
Delta Front Facies	19	24.2	13.9	3.4	18.2	5.3	22	0.1	8.3	0.2
Shelf Edge & Slope Channels	15	18.3	8.9	3.8	16.2	0.7	1.9	0.2	0.7	0.4
Basin Floor Fan	14	17.8	7.7	4.7	17.6	1	1.6	0.1	0.8	1.3



- Mainly lithic-feldarenites and feldarenites reservoirs
- Grain-coatings of illite and chlorite preserved primary porosity
- Most of the analyzed rocks have experienced at least two dissolution processes



Sample 15, showing variability in grain size (red & yellow lines) and in pores size (blue lines)



A-Sample 15 Feldarenite, observed how the grains are settled, leaving large pores between them.

Sample 15			
Process and products	Eodiagenesis	Mesodiagenesis Early Late	Telodiagenesis
Mechanical Compaction			
Dissolution			
Clay coating (I/S, illite, chlorite)			
Secondary quartz grow			
Obliterate clay (kaolinite)			
Dissolution 1			
HC infiltration			
Iron oxide			
	70°C/2km	100°C/+3km	Superficially

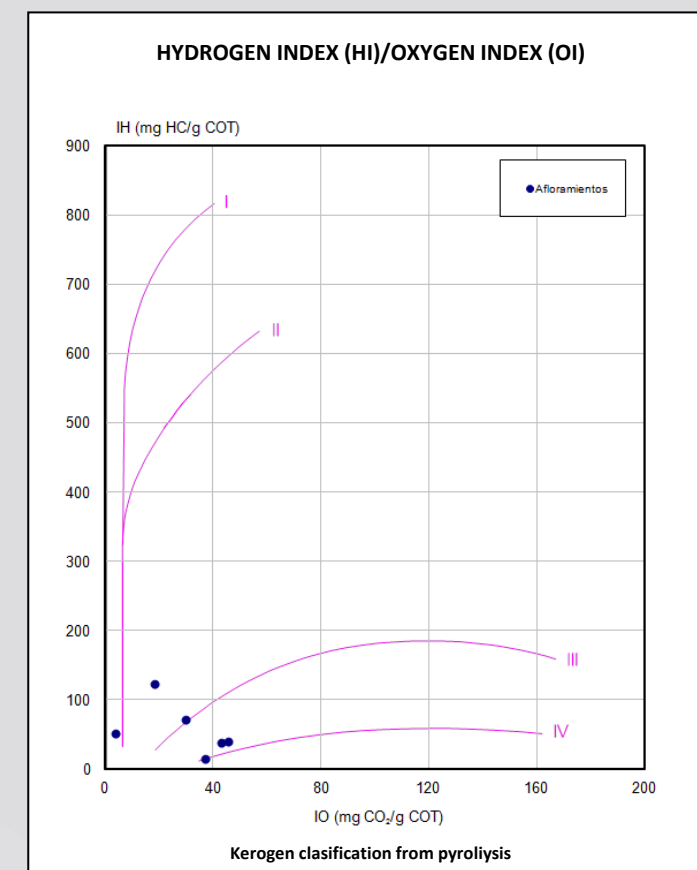
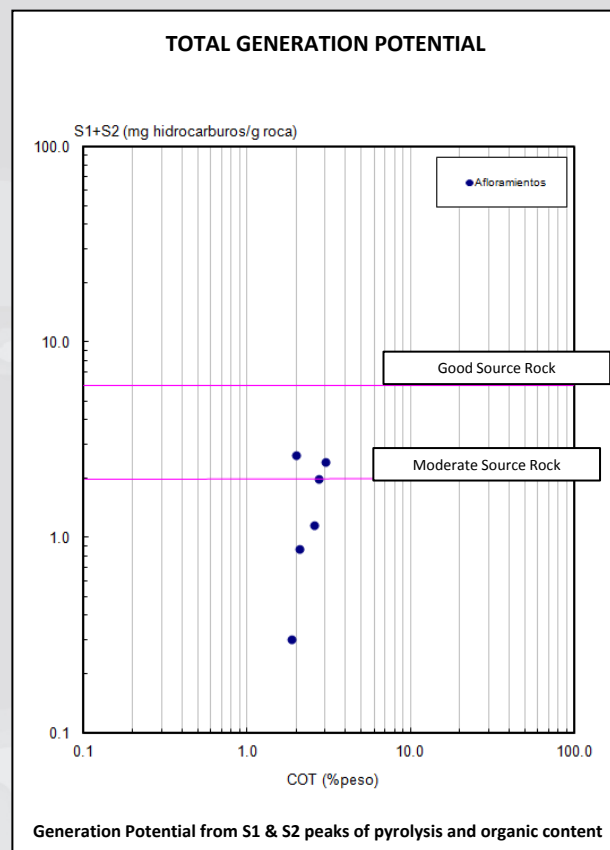
- TOC contents, visual kerogen analysis and pyrolysis, allowed defining Los Molles Fm. as a source rock in Arroyo La Jardinera



● OUTCROP SAMPLES

MUESTRA	TOC %	S1 mg/g	S2 mg/g	S3 mg/g	S1+S2	Tmax°C	S1/COT	S2/COT	S3/COT	S2/S3	S1/S1+S2
3-1- TOC 1	2.01	0.16	2.47	0.37	2.63	439	8.0	123	18	7	0.06
3-1 TOC 2	2.76	0.55	1.44	0.10	1.99	472	20.0	52	4	14	0.28
3-2 TOC 3	1.87	0.03	0.27	0.69	0.30	535	1.6	14	37	0	0.10
3-2 TOC 4	0.08				0.00						
19 TOC	2.09	0.07	0.81	0.90	0.88	457	3.4	39	43	1	0.08
20 TOC	2.59	0.13	1.02	1.18	1.15	455	5.0	39	46	1	0.11
TOC 145	3.03	0.26	2.19	0.90	2.45	452	8.6	72	30	2	0.11

- Kerogen type II/III with fair to moderate oil potential
- All estimations (Vitrinite Reflectance & Thermal Alteration Index) indicate maturities of the samples comprised in the late oil generation stage

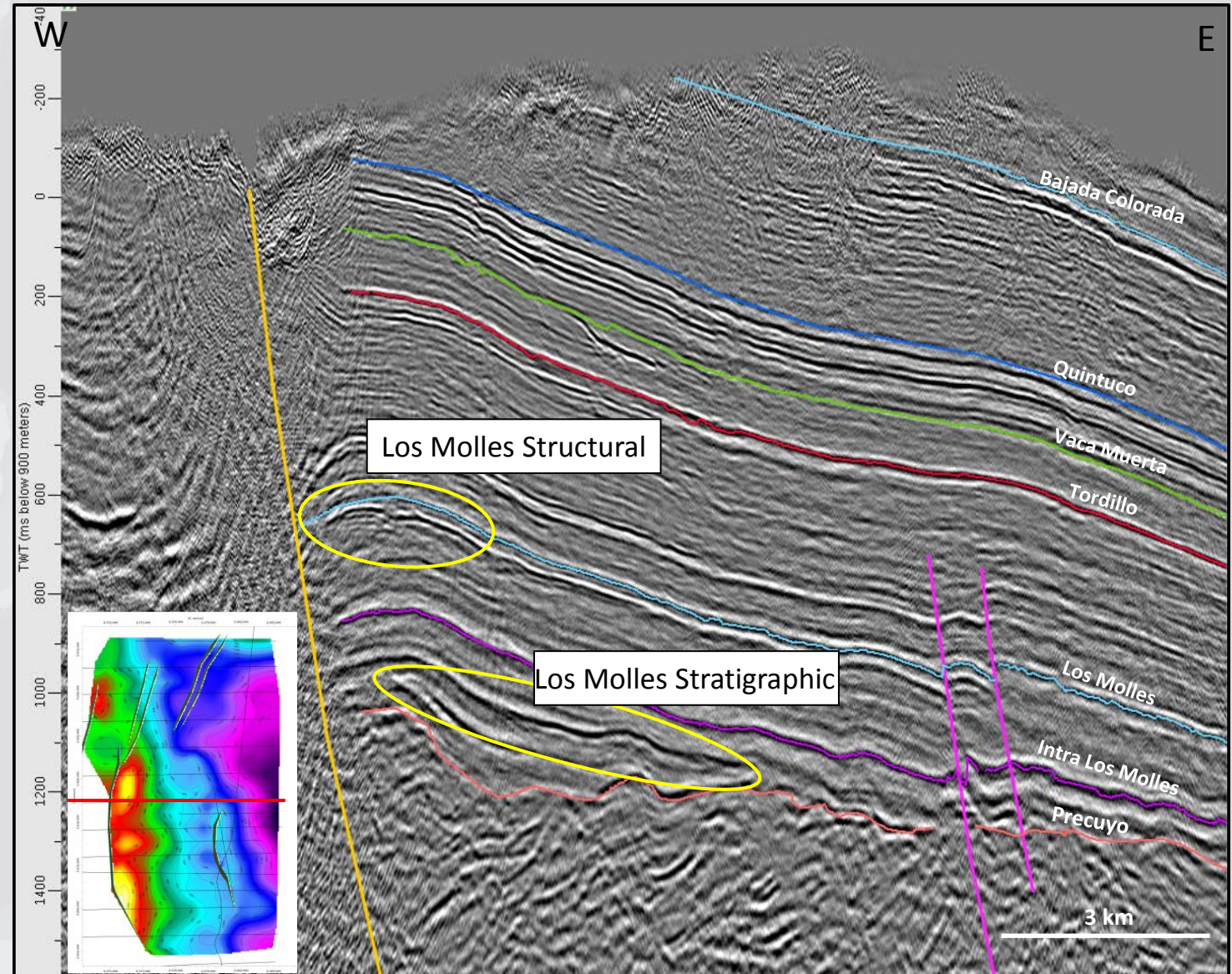


Subsurface Play Definition



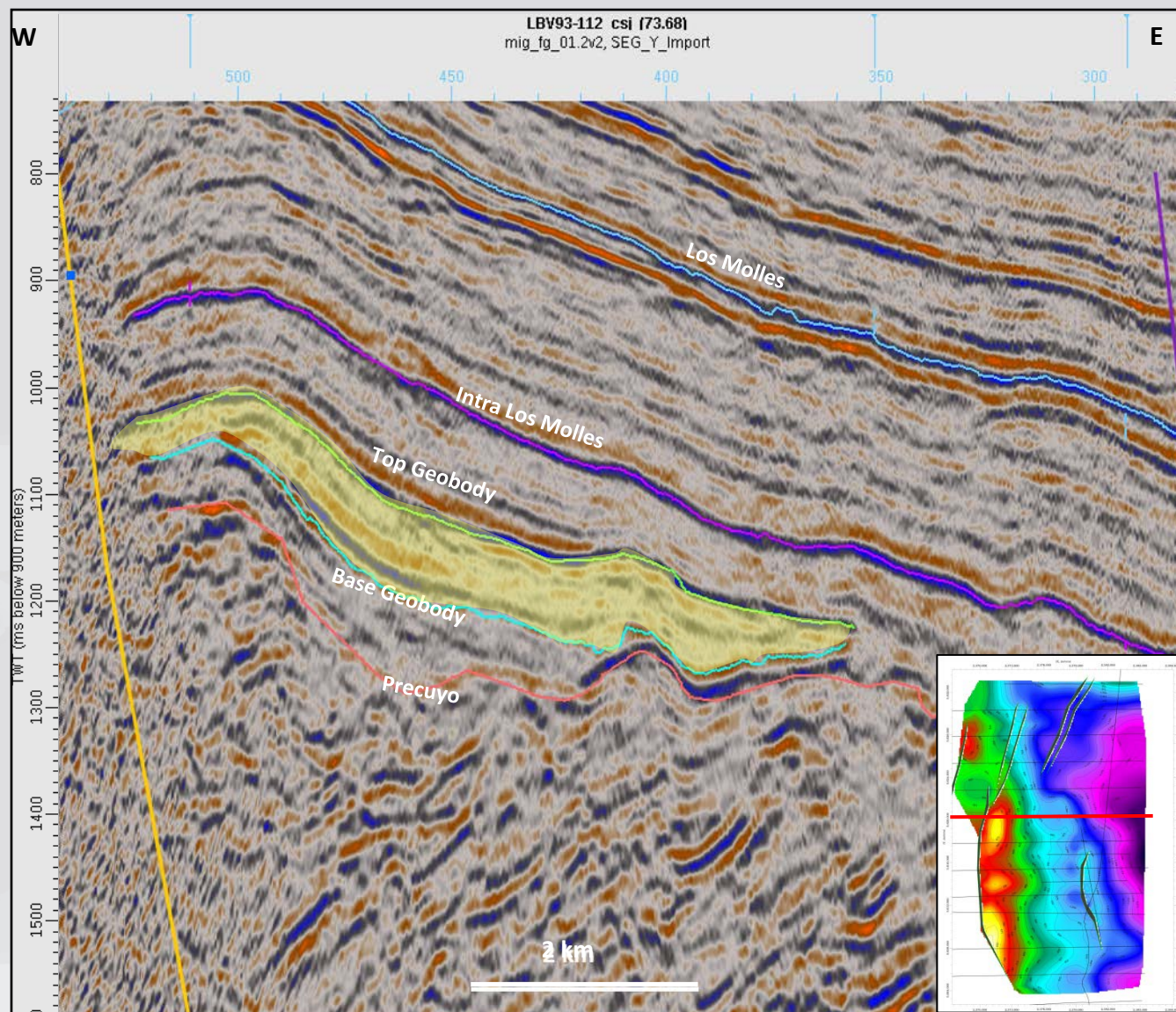
- At least 2 different plays considered for Las Coloradas zone:

- Los Molles structural 4WC (no well on the structure reached this Fm.)
- Los Molles stratigraphic pinch out against structural high



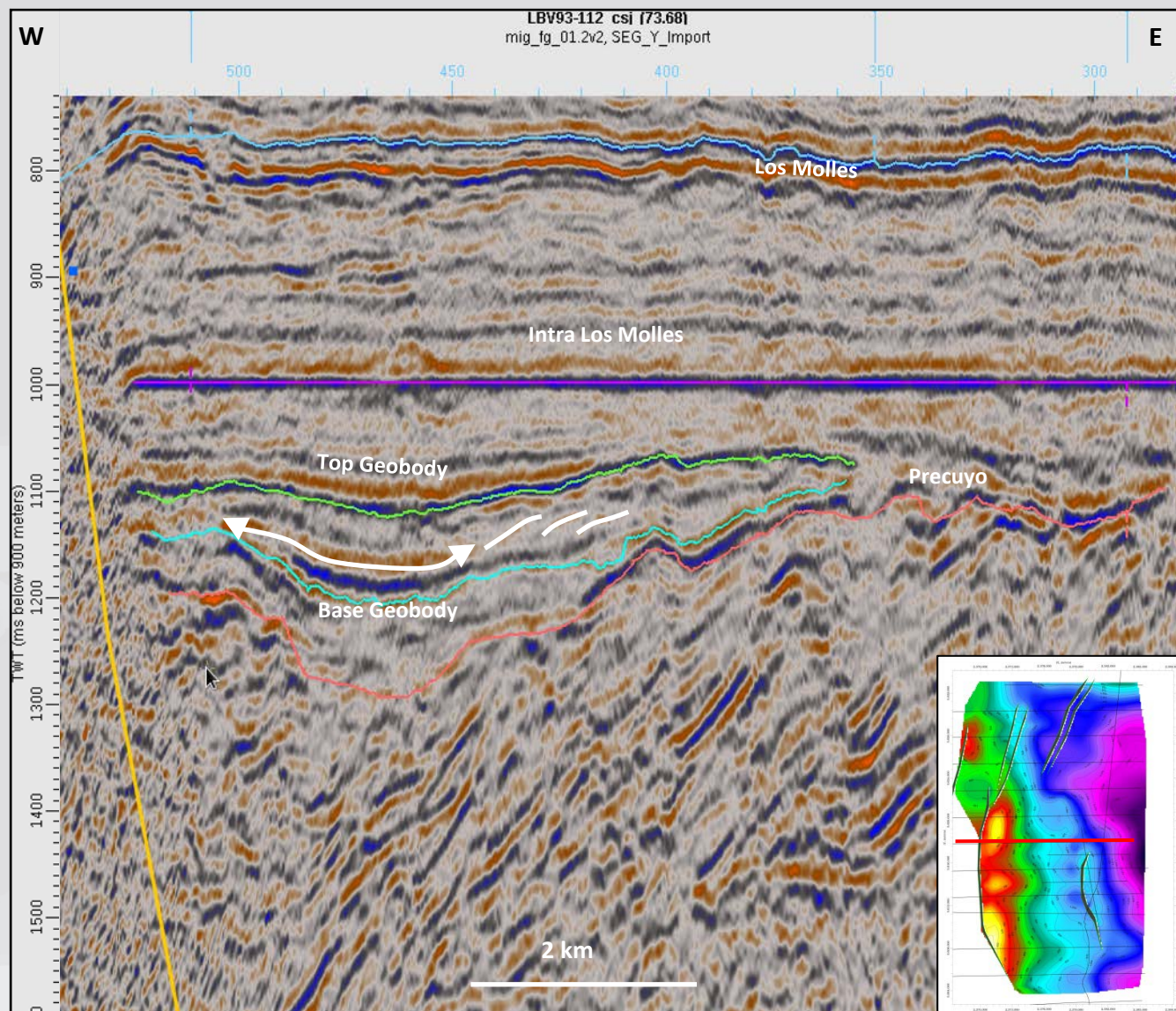
LAS COLORADAS-CHANNEL STRUCTURAL -STRATIGRAPHIC PLAY

- Channelized feature identified in 2D within Los Molles Fm.
- Channel axes strike aligned with paleomargin progradation direction
- Combined structural/stratigraphic trap defined



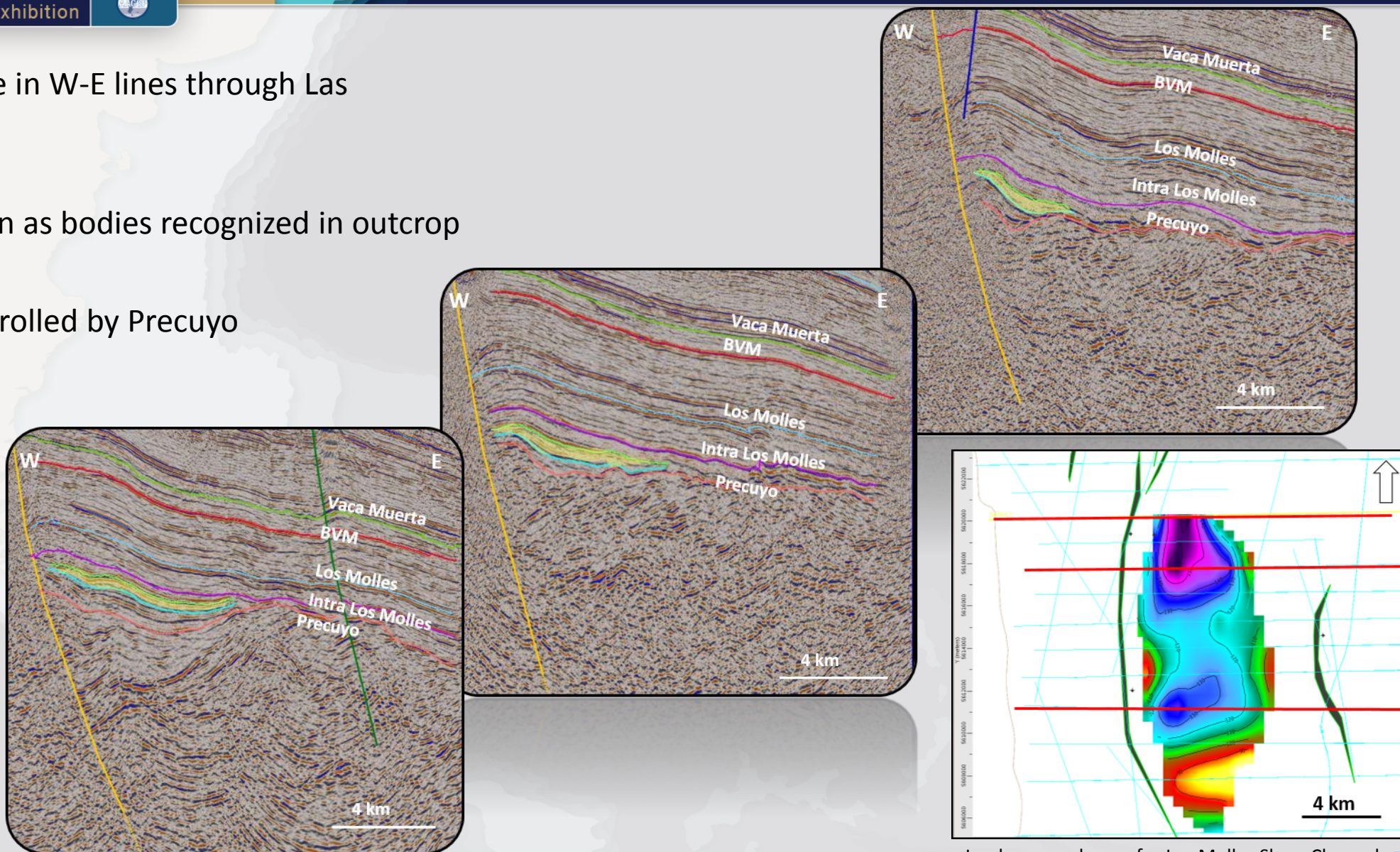
LAS COLORADAS-CHANNEL STRUCTURAL -STRATIGRAPHIC PLAY

- Flattened section to Intra Los Molles allows identifying potential lateral accretion of channel migration
- Same age, equivalent geometries identified to the NE



LAS COLORADAS-CHANNEL STRUCTURAL -STRATIGRAPHIC PLAY

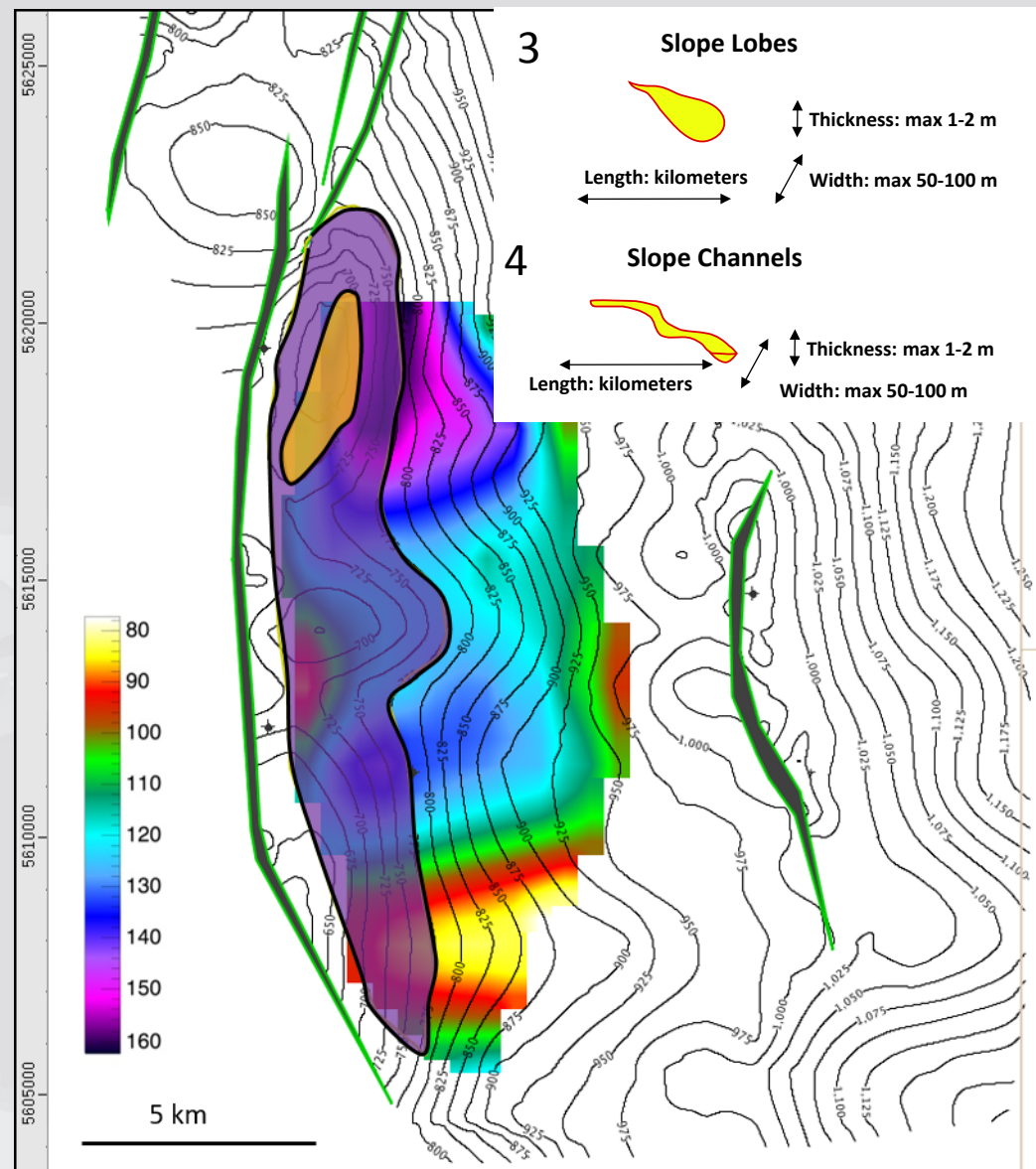
- Channelized feature in W-E lines through Las Coloradas structure
- Same paleodirection as bodies recognized in outcrop
- E-W extension controlled by Precuyo paleotopography



Isochronopach map for Los Molles Slope Channel

LAS COLORADAS-CHANNEL STRUCTURAL -STRATIGRAPHIC PLAY

- Combined structural-stratigraphic prospect defined for the Los Molles deposits
- Equivalent to play Type 3 or 4
- Thickness, NTG and porosities distribution were considered from these analogs



TWT Isochrone Contours and isochronopach map for Los Molles Slope Channel

1. Detailed outcrop studies, petrophysical, petrographic and geochemical analyses provided new information regarding paleoenvironmental configurations, reservoir characteristics and source rock presence for the Laguna Blanca Block
2. Prospectivity of the block was redefined through several stratigraphic plays
3. Remaining potential was defined for the block at the Los Molles stratigraphic/structural prospect
4. Multidisciplinary approach to reassess the potential of a region that has been largely overlooked

ACKNOWLEDGMENTS

