

New insights on the Lower Jurassic petroleum systems and deep gas play of the Neuquen basin, Argentina.

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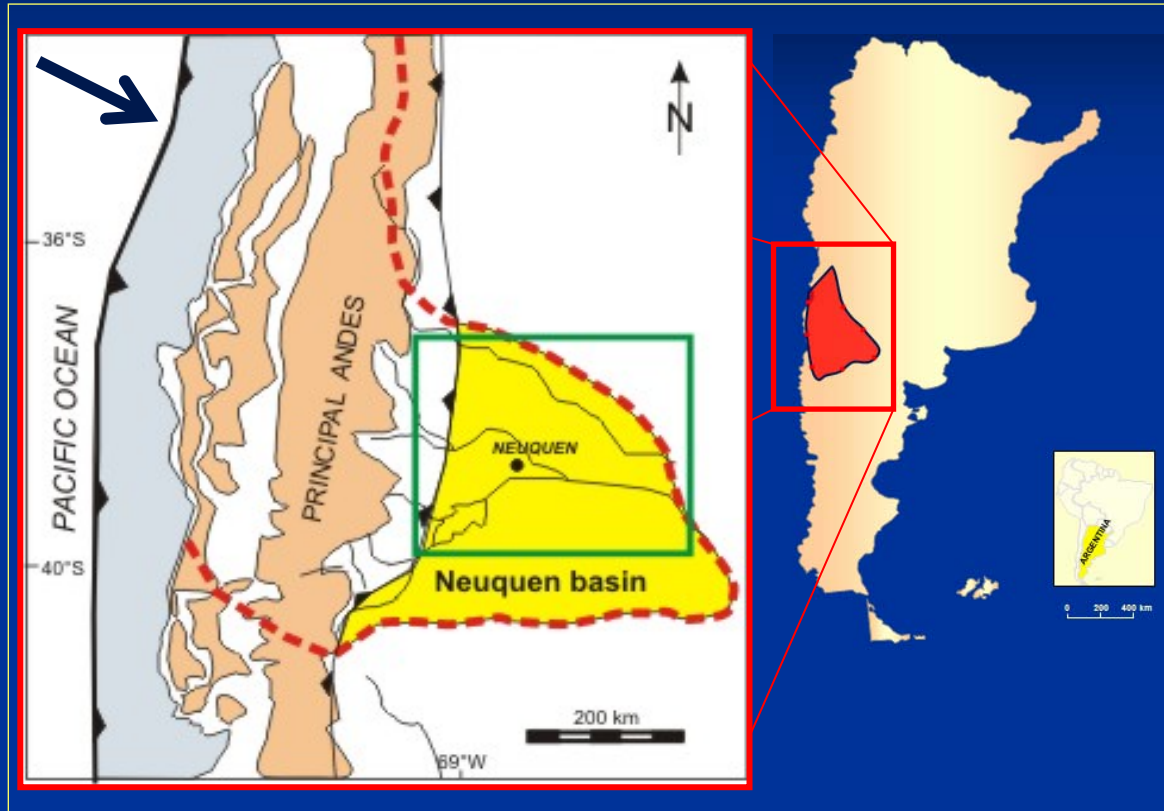


Objectives

- Introduce a **novel migration drainage model** for the hydrocarbon accumulations sourced from the **Lower Jurassic Los Molles Fm.** in the **northeast margin of the Neuquen basin.**
- Postulate the existence of a **new deep gas play** defined by:
 - **The pinch-out of the braid delta and shellfall lobe deposits** of Los Molles Fm. along **the hinge line** of the NE margin.
 - The presence **of two porosity preserving processes**:
 - **Chlorite rims** development at early diagenetic stages,
 - **Early migration of oil** into the reservoir, prior to critical burial.
 - The existence of a **source – reservoir system**, conformed by laterally linked and time equivalent units.
- Emphasize once more **that paradigm shifts** resulting from new-simple and supported ideas are a powerful tool **to revitalize mature basins**

Regional Setting

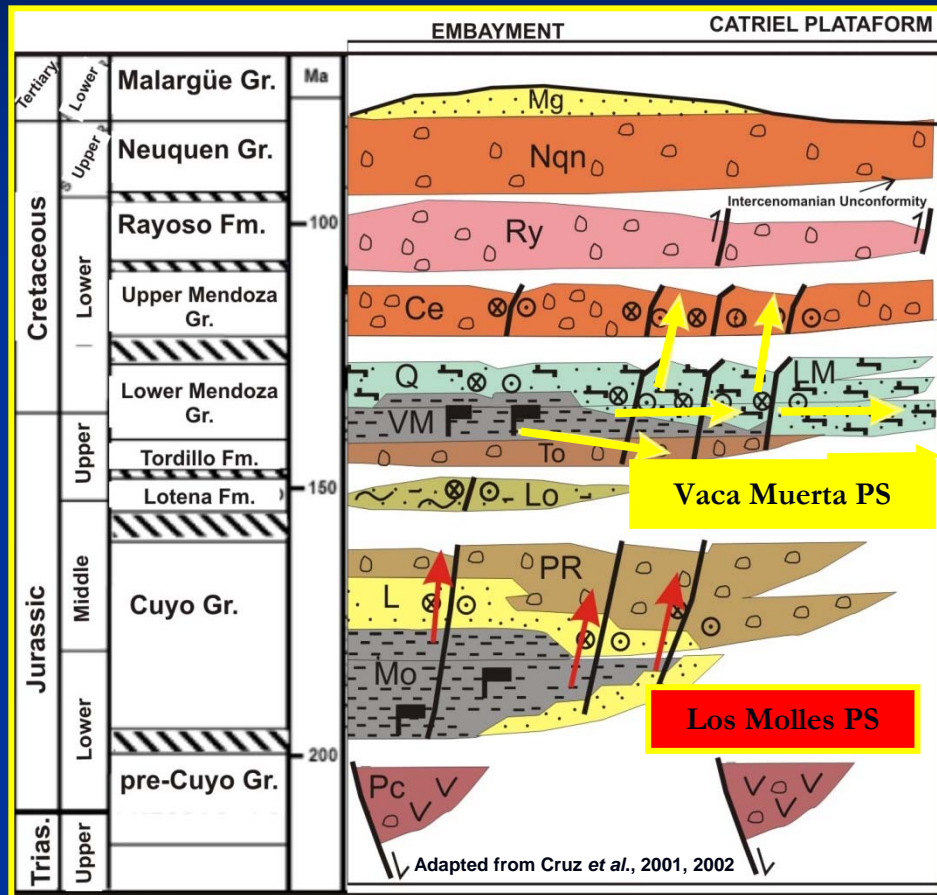
Location Map



- Southern portion of the Central Andes
- Lower Jurassic – Tertiary back arc-foreland basin
- Over 6000m of total sedimentary fill, mostly of Jurassic and Cretaceous age.
- Jurassic - Early Cretaceous intraplate back arc deformation stage
- Upper Cretaceous-Miocene F&TB – foreland stage
- Neuquen embayment : portion east of the Agrio F&TB orogenic front.

Stratigraphy and Source Rocks

Chronostratigraphic Chart



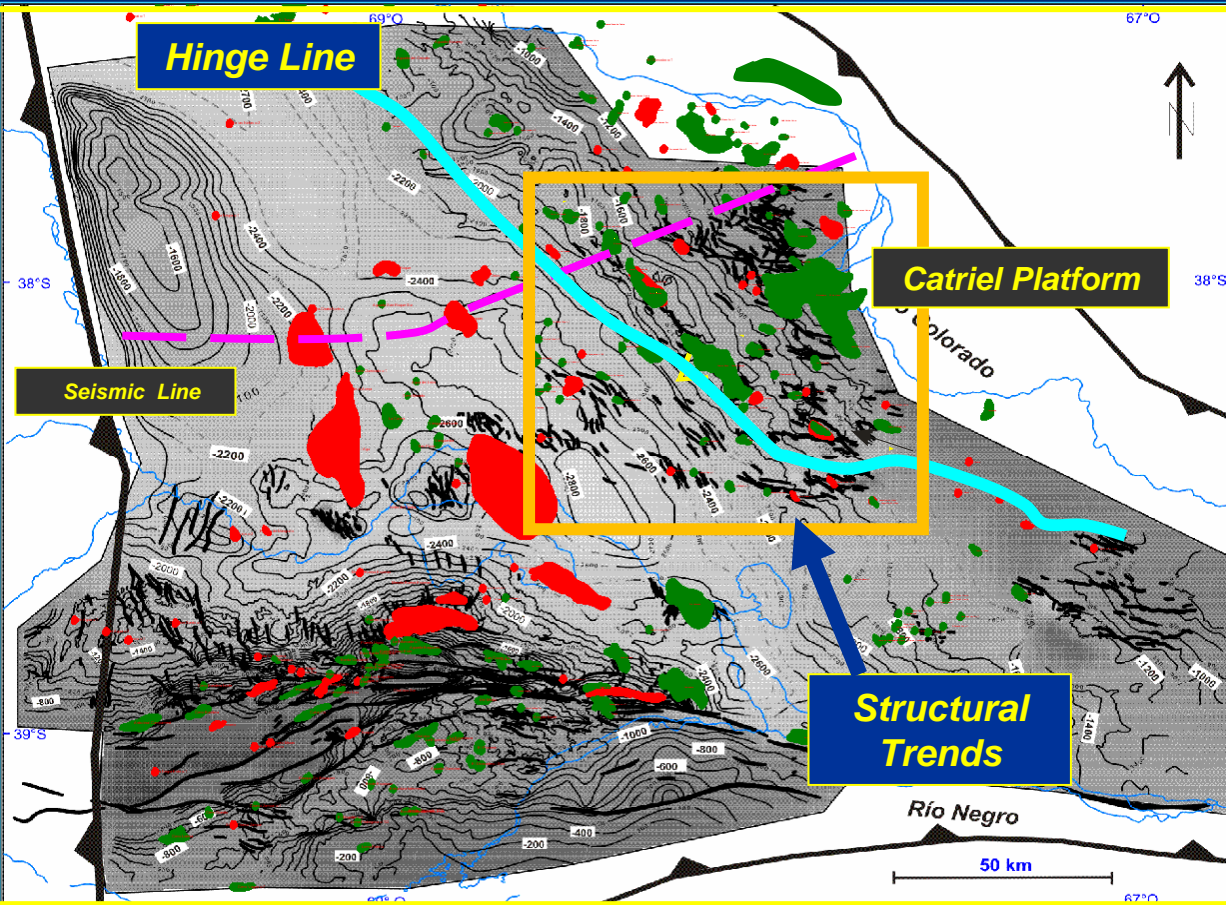
Vaca Muerta PS vs. Los Molles PS

- Anoxic marine, very rich, high-quality, Type II kerogen, platform to deep basinal facies.
- Good quality Type II/III-(III), mixed marine-terrestrial, More oil-prone lower section versus more gas-prone upper section.
- Naphtene-paraffinic, intermediate to light oils (30-40° API), mid to high maturity ranges, low to moderate, occasionally high, sulfur content.
- Light to very light (35-60° API), low-sulfur crude oils/condensates and gas.
- Marine anoxic signature. Carbonate-richer (platform) to shaly (basinal) organic facies.
- Marine signature with variable terrestrial contribution; moderately reducing to suboxic environment.
- Much less negative isotopic range ($\delta^{13}\text{C} \sim -27$ to -30 ‰) than that of Los Molles PS ($\delta^{13}\text{C} \sim -30$ to -32 ‰).
- Long distance lateral migration
- Dominant, fault-controlled, vertical migration.

Source Rock	Hydrocarbons (Bkg)		GAE
FM	Generated	In - situ	%
Los Molles	300,000	550	0.2
Vaca Muerta	430,000	6000	1.5

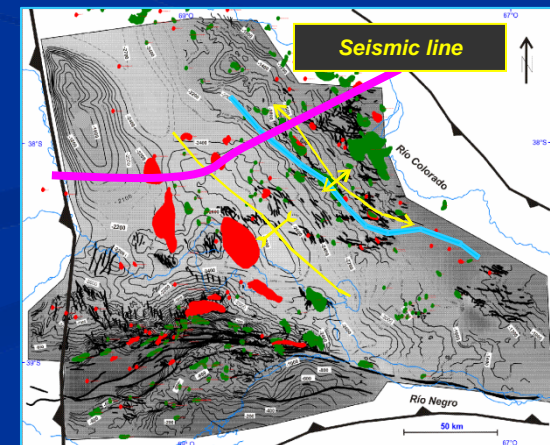
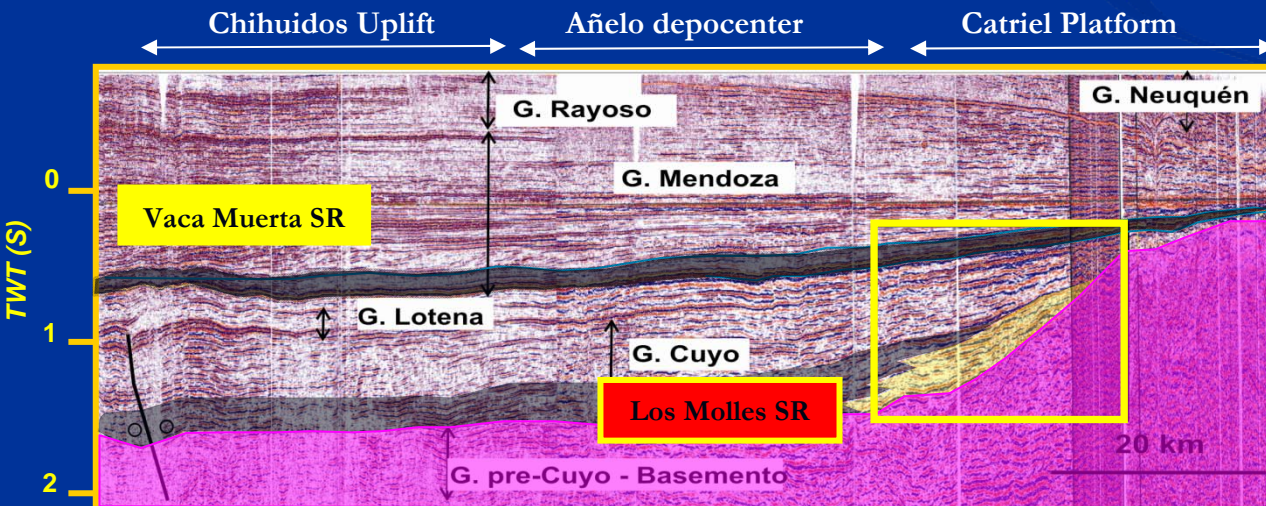
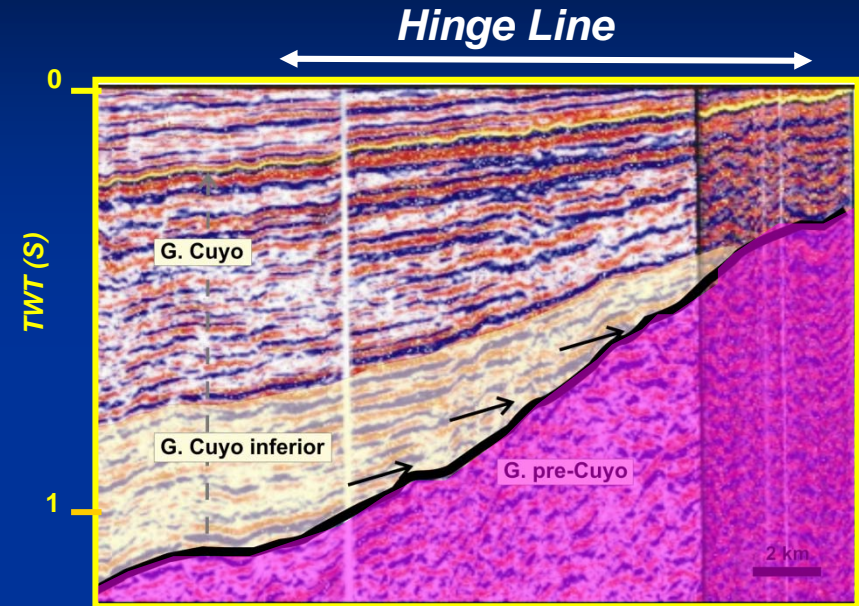
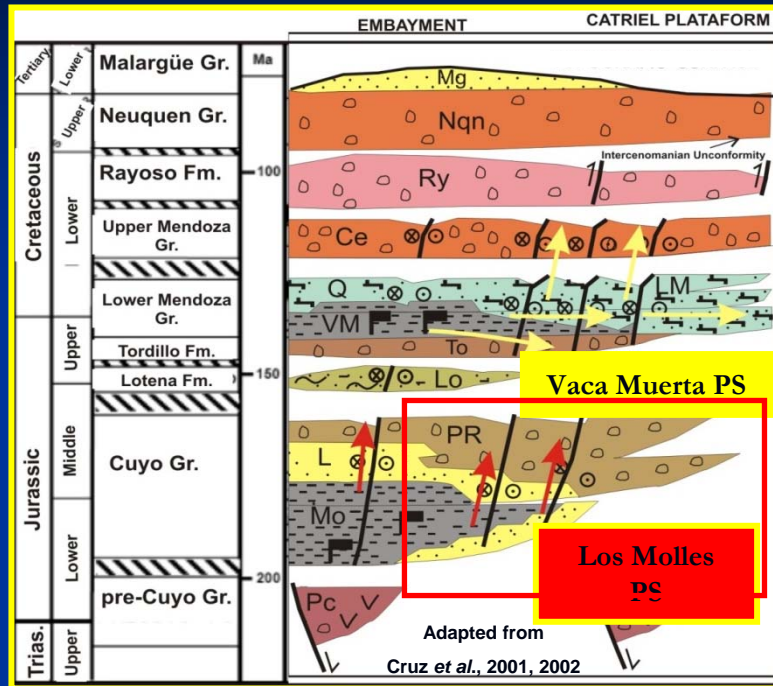
Neuquen Embayment

Depth Structural Map top Vaca Muerta Fm.



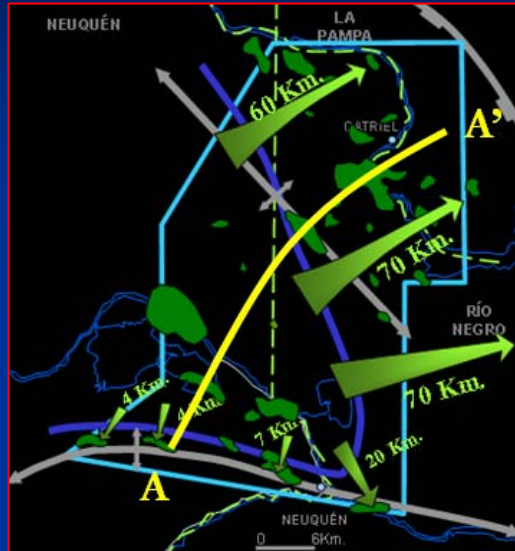
- Embayment Sectors EUR
- **BASIN EUR: 10,000 MMBOE**
- Huincul system 2000 MMBOE
- Basin center: 3600 MMBOE
- Catriel Platform: 1500 MMBOE
- **HINGE LINE**
- **FAULT SYSTEMS**
- **BASIN MATURITY**
- ★ • **DEEP GAS CENTER (> TCF)**
- **HEAVY OIL BELT**

Hinge Zone

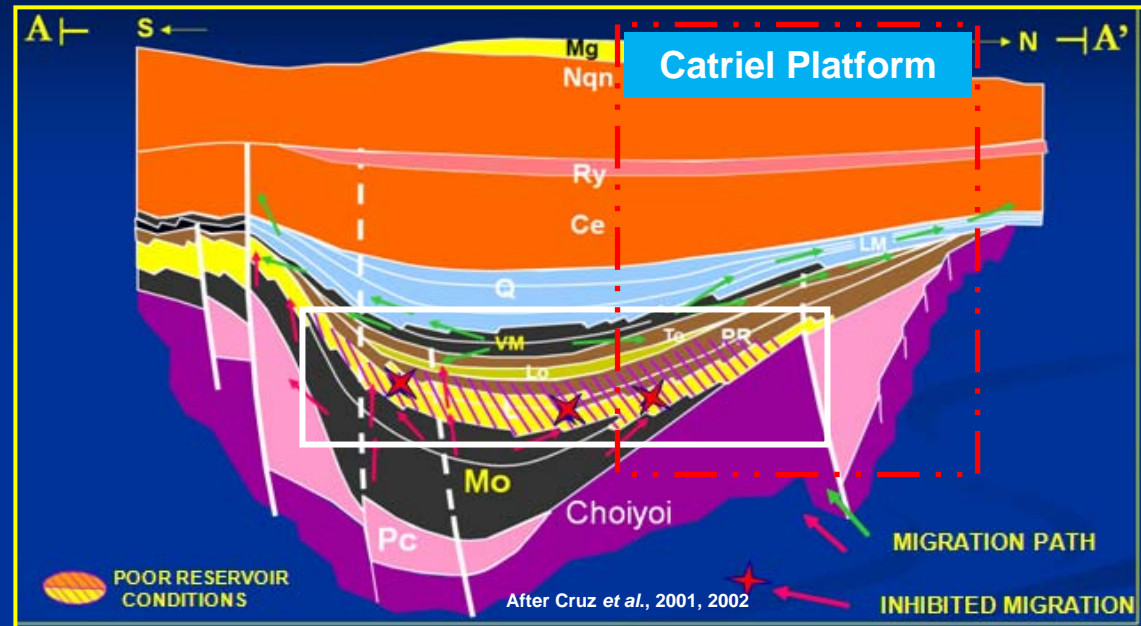


Migration drainage styles – Present knowledge status

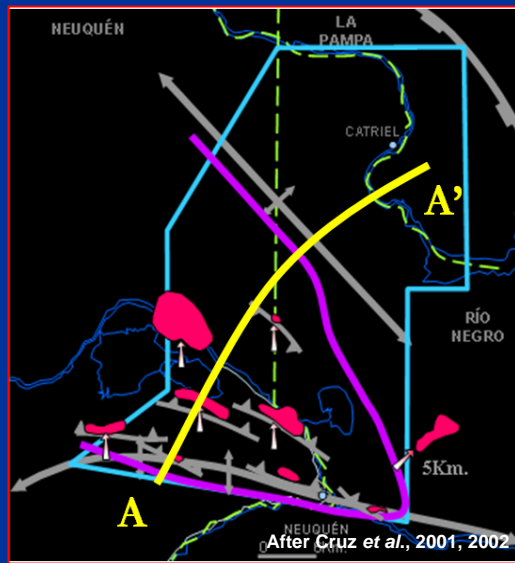
Vaca Muerta



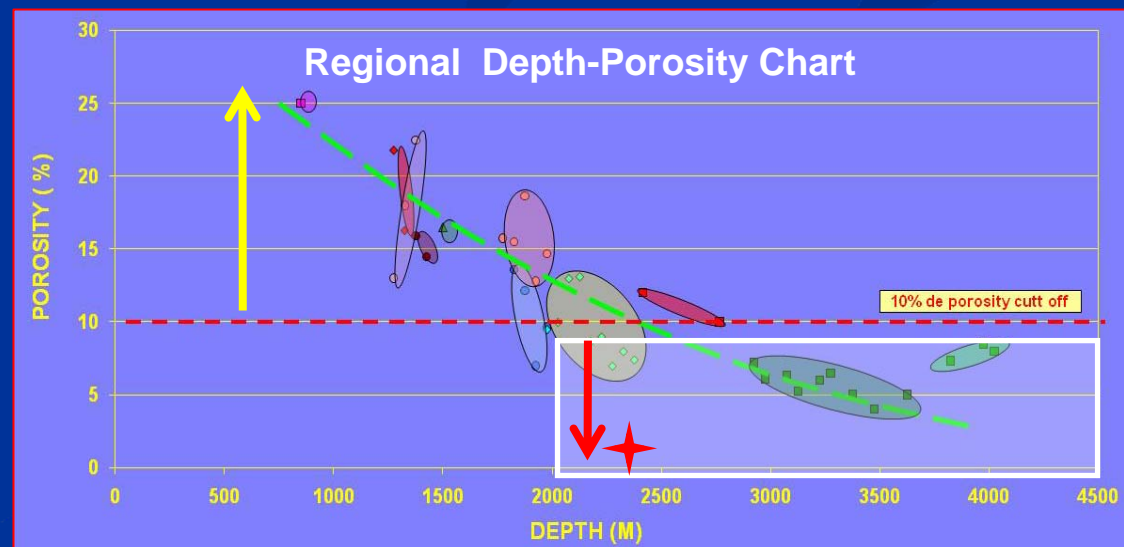
After Cruz et al., 2001, 2002



Los Molles

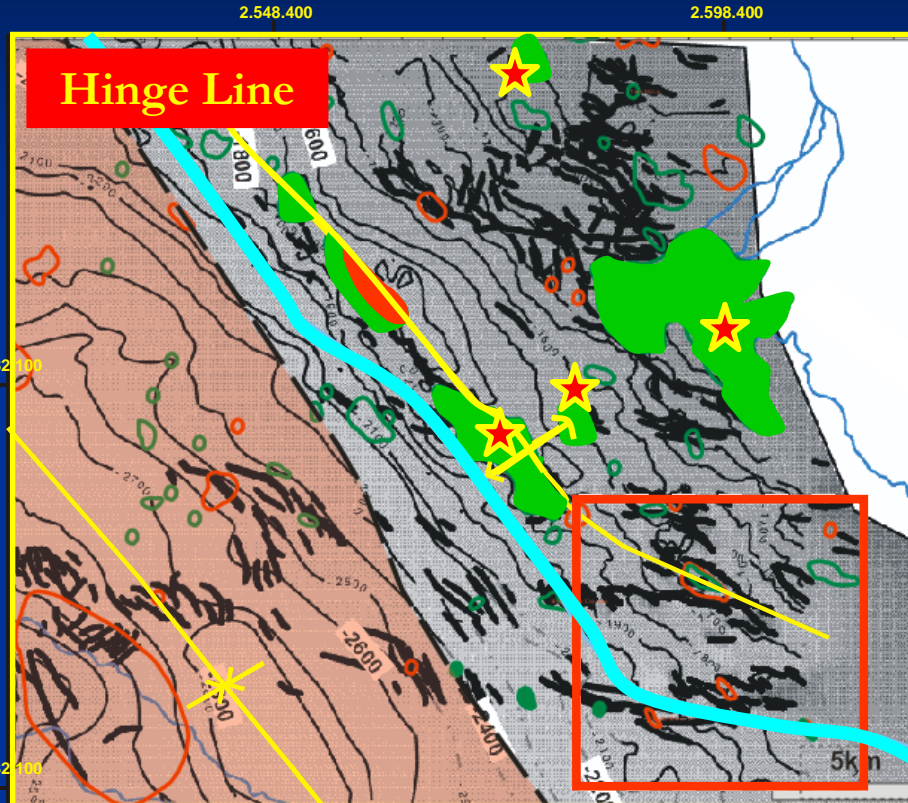


After Cruz et al., 2001, 2002



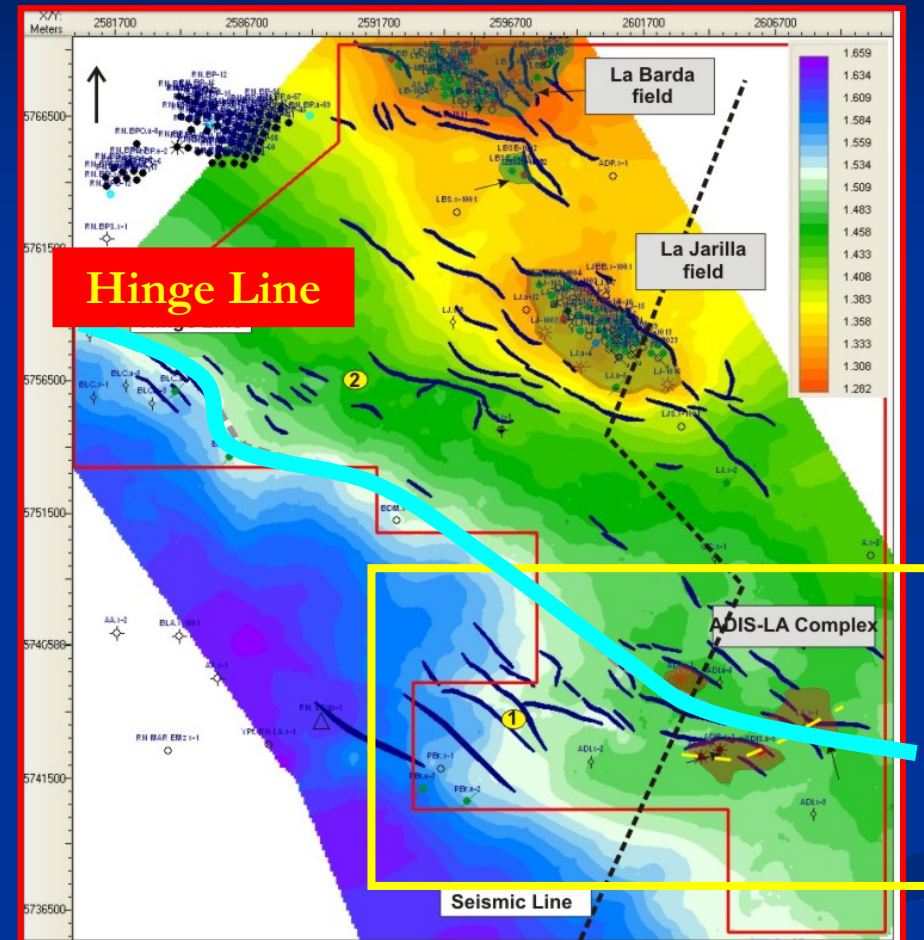
Study Area

Catriel Platform Southern Portion



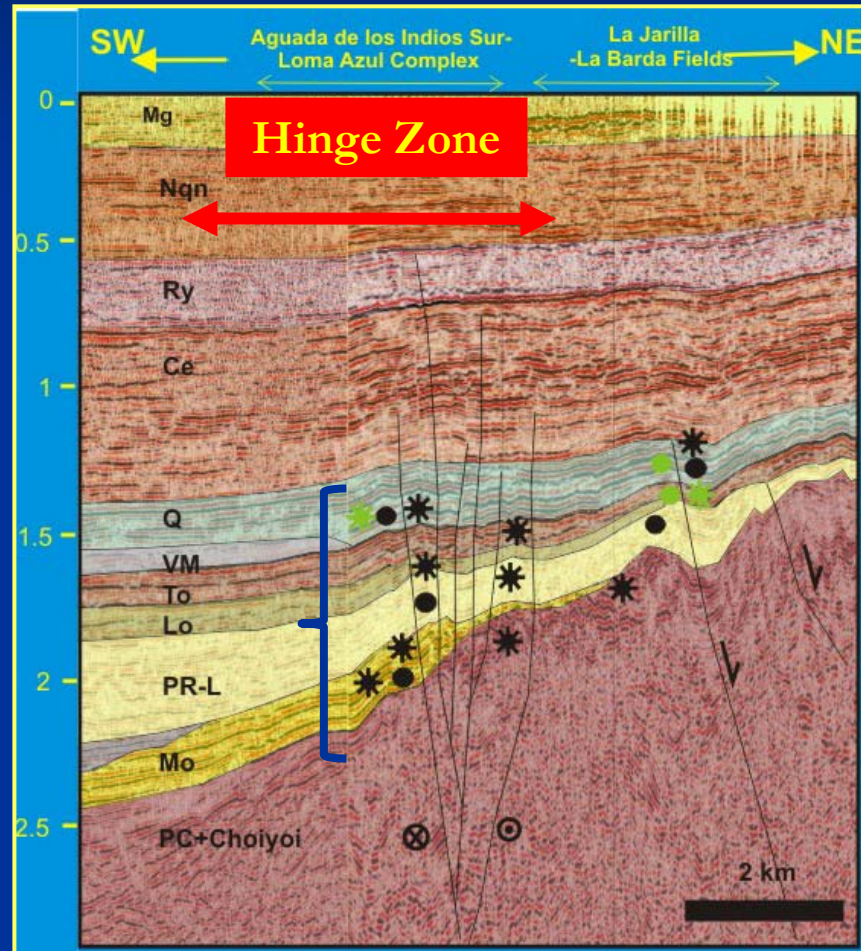
- EUR: 1000 MMBOE
- ★ 85 % of the reserves are in 4 V. Large-Large fields (AAPG field size classification)
- VACA MUERTA HYDROCARBON REGION
- Low deep explored hinge zone

Agua Salada Block



Aguada de los Indios Sur - Loma Azul Complex

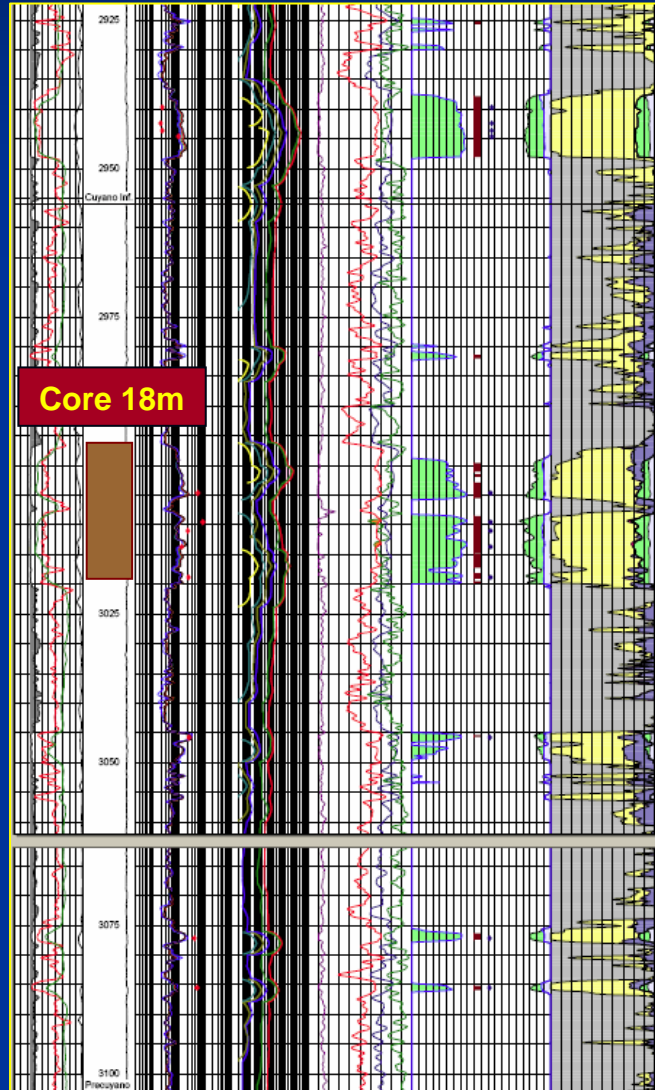
Seismic Section



- **Medium size field discovery 42 MMBOE** of 3P reserves with **40 MMBOE additional upside** (large size field)
- Area: 20 km², V. Closure: 100m, 130 m of net pay
- Filled to spill point, 2000-**3000** mbkb depth ranges
- **Genetically related Gas and Oil** accumulations vertically distributed in 1000 m of continuous HC columns

Los Molles Fm. Reservoir - Properties

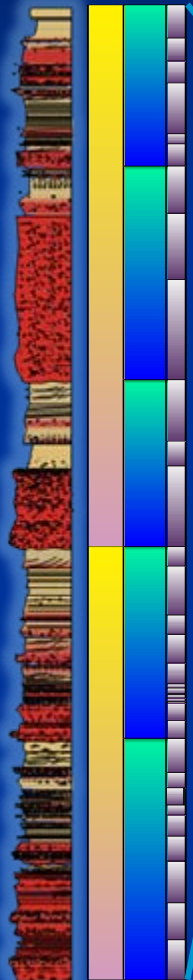
Type Log



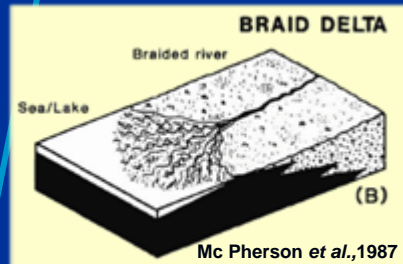
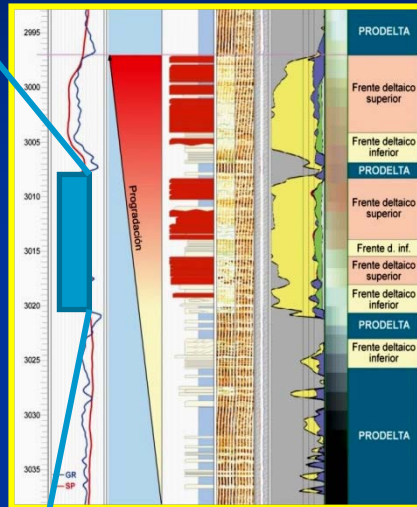
- **Poorly explored objective**
- **Critical depth ranges 2900-3200mbkb**
- **Multilayer –single reservoirs: 40m net pay.**
Reservoir lithology, medium sandstones to conglomerates **good to excellent (gas) quality reservoirs**
- **Porosity: 12- 15%, permeability up to 100 Md.**
- **Over 10 MMCF/d of initial gas flow and 700 Bbls/d of initial oil flows without hydraulic stimulation from 2-4 m thick layers.**
- **Sustainable flow through time.**

Los Molles Fm. Reservoir – Depositional system

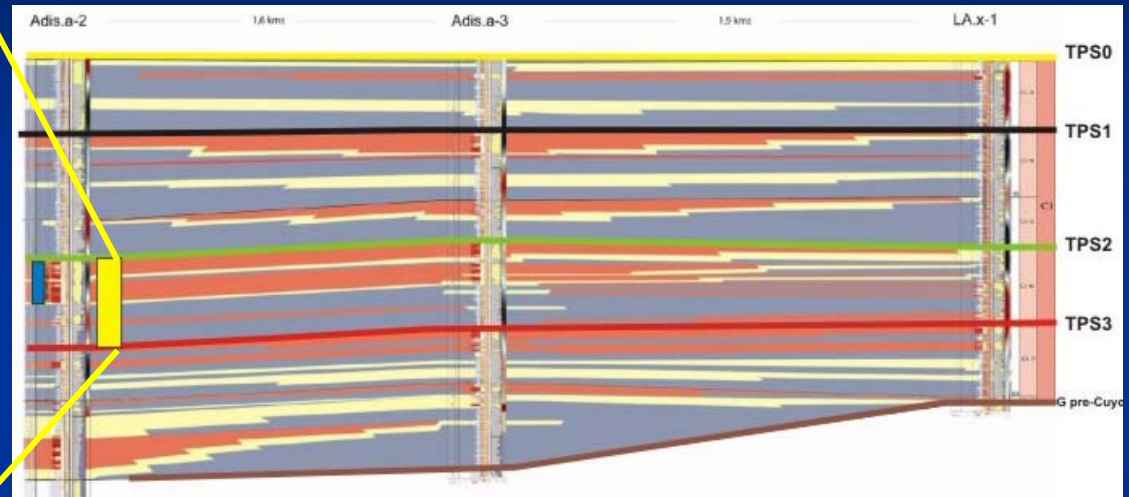
Core Data



Vertical facies association



High resolution stratigraphic section



- **Braid deltaic constructive system**, high subsidence rates , low grade slopes and up to **hundreds km² of extension**.

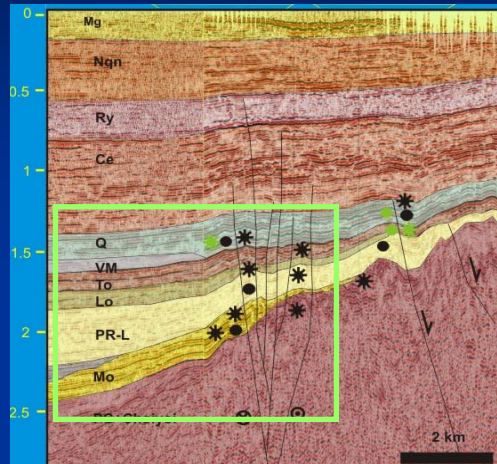
- **Marine marginal to fluvio-deltaic** environment, abundant organic matter and low grade oxidant conditions according to **palinofacies analysis**.

- Eight coarsening and thickening upward elementary sequences grouped in **4 parasequence sets**

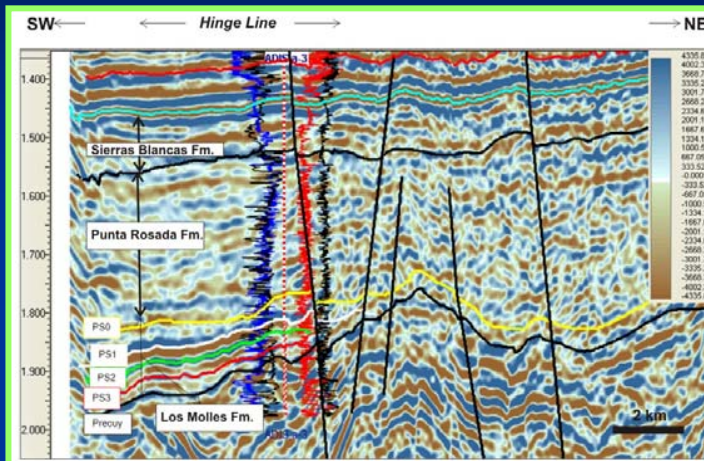
- **Progradational system separated** by regional flooding events controlled by **alocyclic factors**.

Geological and geophysical modelling

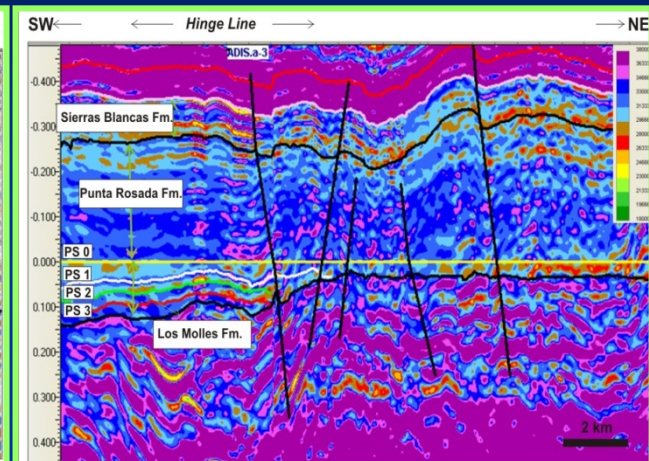
Location



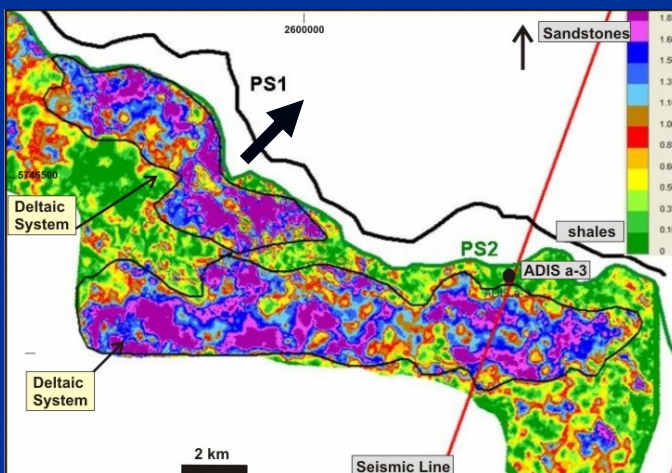
Amplitudes



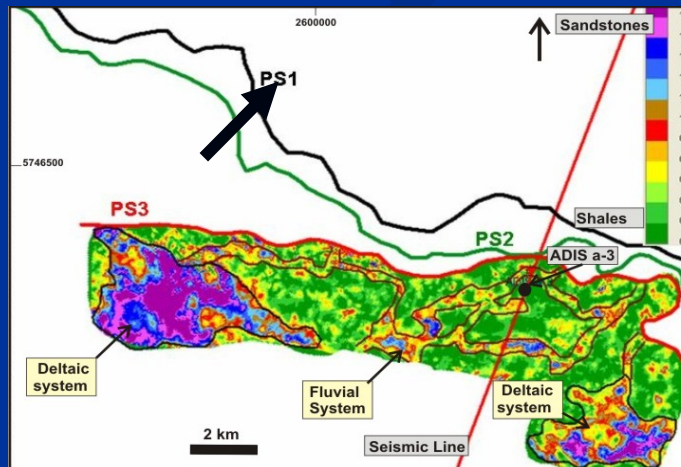
Acoustic Impedance



PS 2 Porosity Cube Extraction



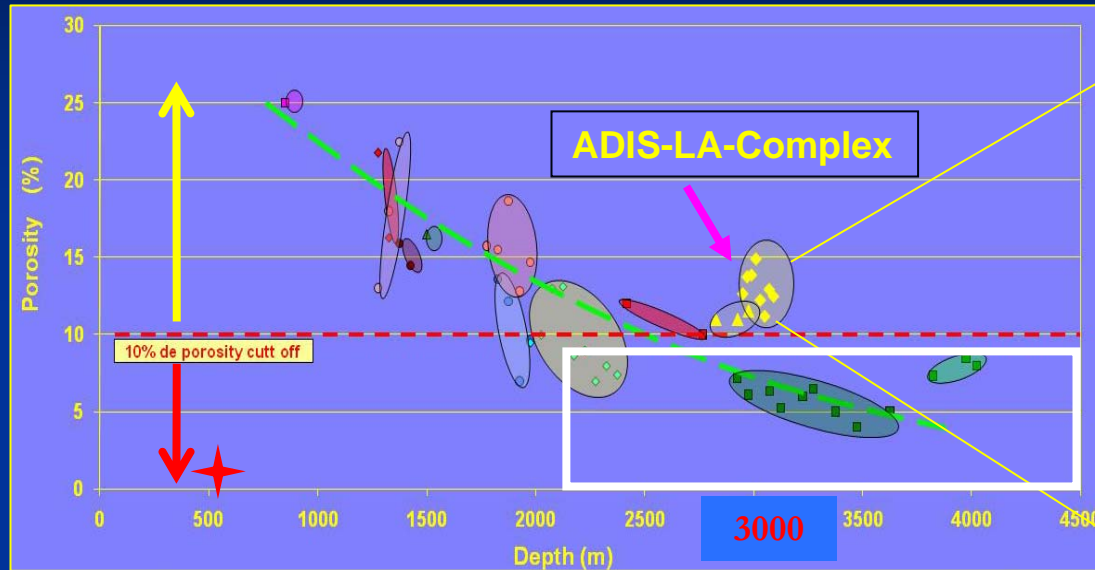
PS 3 Porosity Cube Extraction



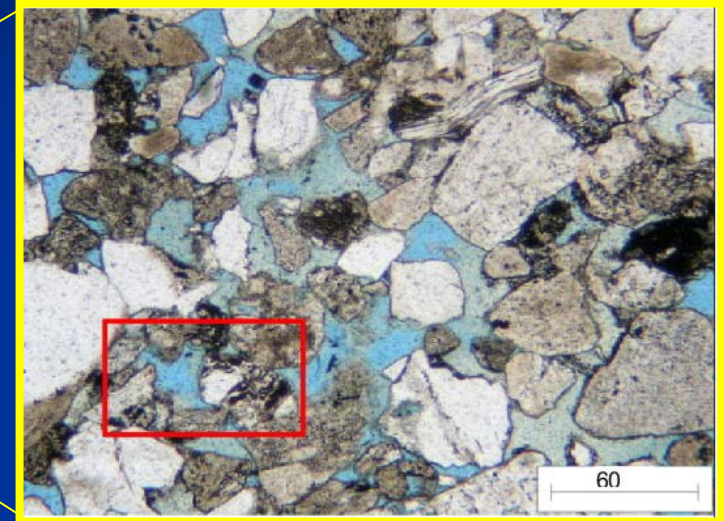
- **Retrogradational** arrangement
- High amplitude and continuous seismic events.
- **Lobular geometries, parallel to the depositional edge.**
- Lithology

Petrographic and Diagenetic Studies

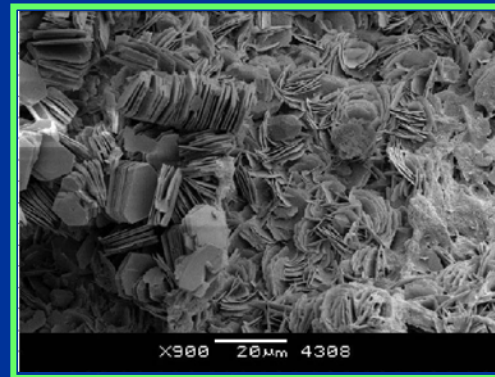
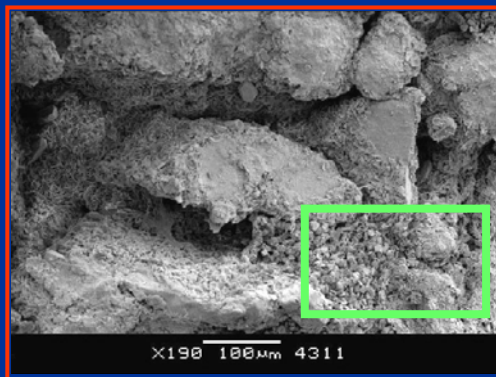
Regional Depth - Porosity Chart



Thin Section



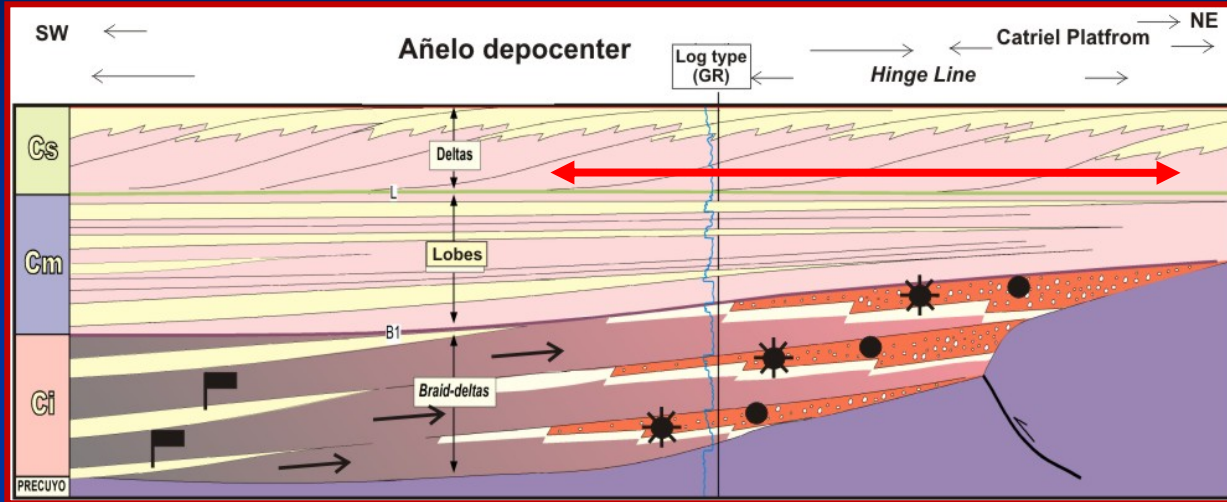
SEM



- Lithic - feldspathic sandstones (25 % metamorphic quartz and lithics)
- Intergranular porosity-Mesopores
- Porosity and permeability preserving chlorite rims (*coating*) - first and generalized diagenetic process.
- Quartz overgrowth and compaction inhibition.

Los Molles Fm. Deep Gas Play

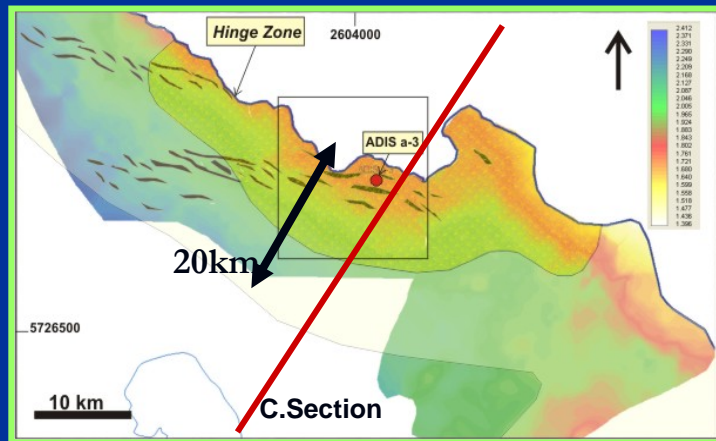
Schematic Geological Cross Section



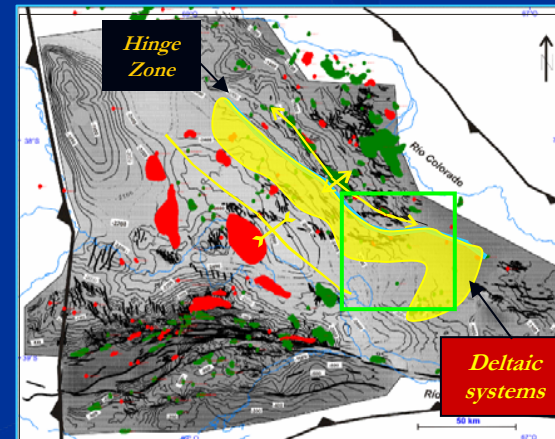
Play elements

- Pinch-out of braid-delta deposits along a 150km long hinge line.
- Multilayer reservoirs with efficient top seals given by transgressive shales.
- Anomalous and excellent proved reservoir conditions at critical burial depths, (extensive coating of chlorite rims and early migration of oil)

Braid Delta System Extension



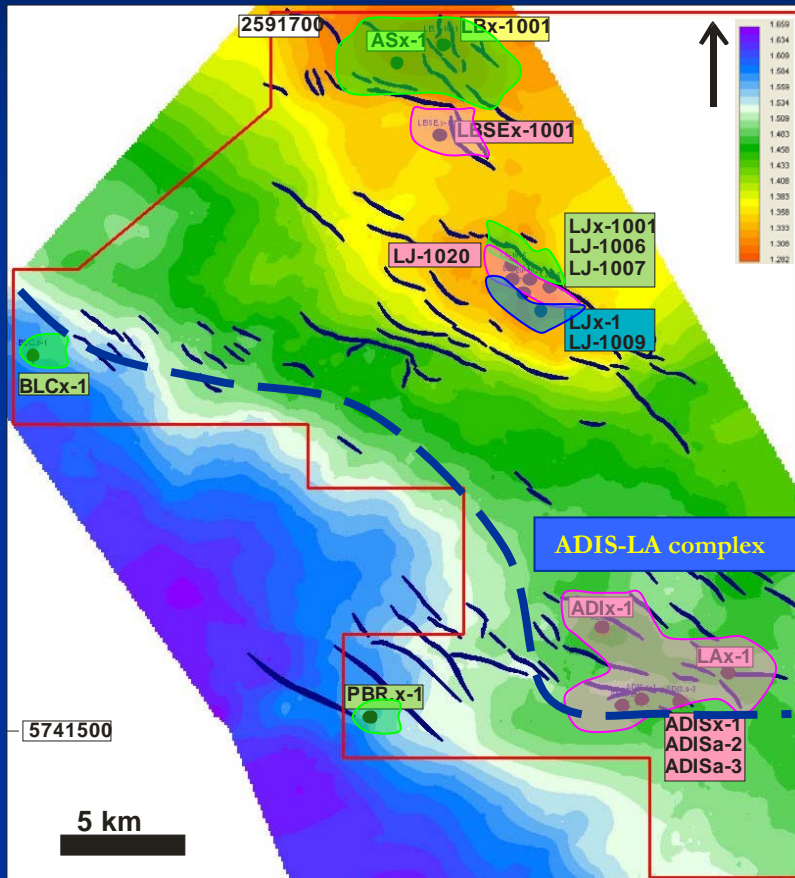
Play Areal Distribution



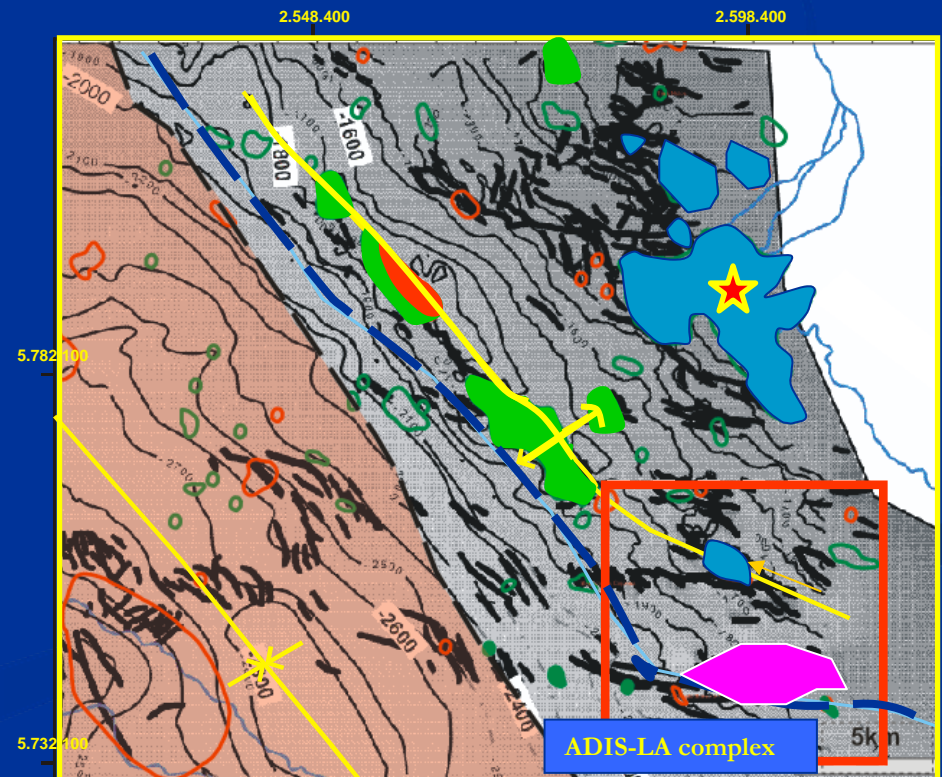
- Large scale deposits (metamorphic sst composition- hinge line extension)
- Efficient source- reservoir system (direct proved lateral charge)
- Potential large-very large field sizes (> TCF).(Sawang field >1 tcf, Pakistan.

Oil Geochemistry

Control Points



- VACA MUERTA** (Oil and condensate hosted in Loma Montosa and Sierras Blancas Fms. reservoirs)
- LOS MOLLES 1** (Oil and condensate hosted in Cuyo Gr. reservoirs)
- LOS MOLLES 2** (Oil and condensate hosted in Loma Montosa Fm. reservoirs)

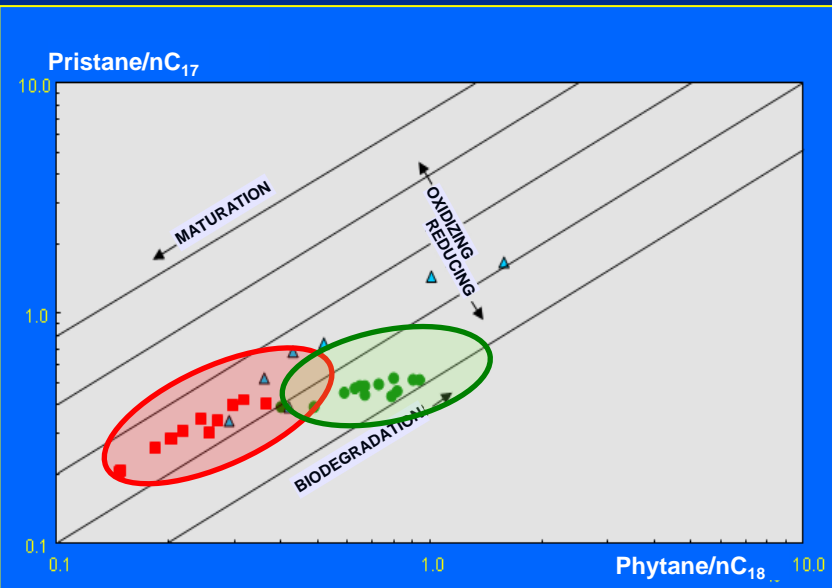


- Identification of Los Molles sourced hydrocarbons in the largest field of the Catriel platform.
- Inferred regional distribution.

Oil Geochemistry

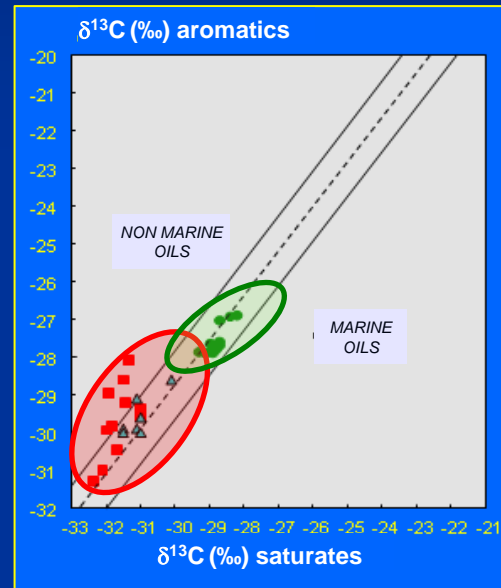
Los Molles oils are readily distinguished from Vaca Muerta oils by means of GC parameters, carbon isotope signatures and biomarker fingerprints.

Gas Chromatography



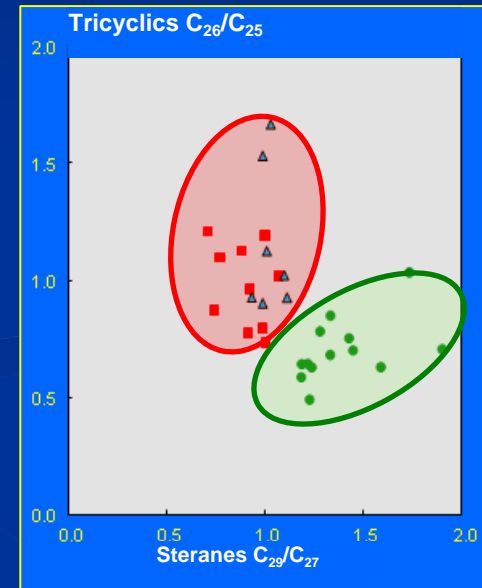
Suboxic marine with terrestrial contribution (LM) versus marine anoxic (VM).

Carbon Isotopes



Much more negative $\delta^{13}\text{C}$ (‰) signature for LM compared to VM oils.

Biomarkers



C_{29} prevailing over C_{27} steranes in LM oils (terrestrial input).

Relatively high $\text{C}_{26}/\text{C}_{25}$ tricyclics terpane ratios.

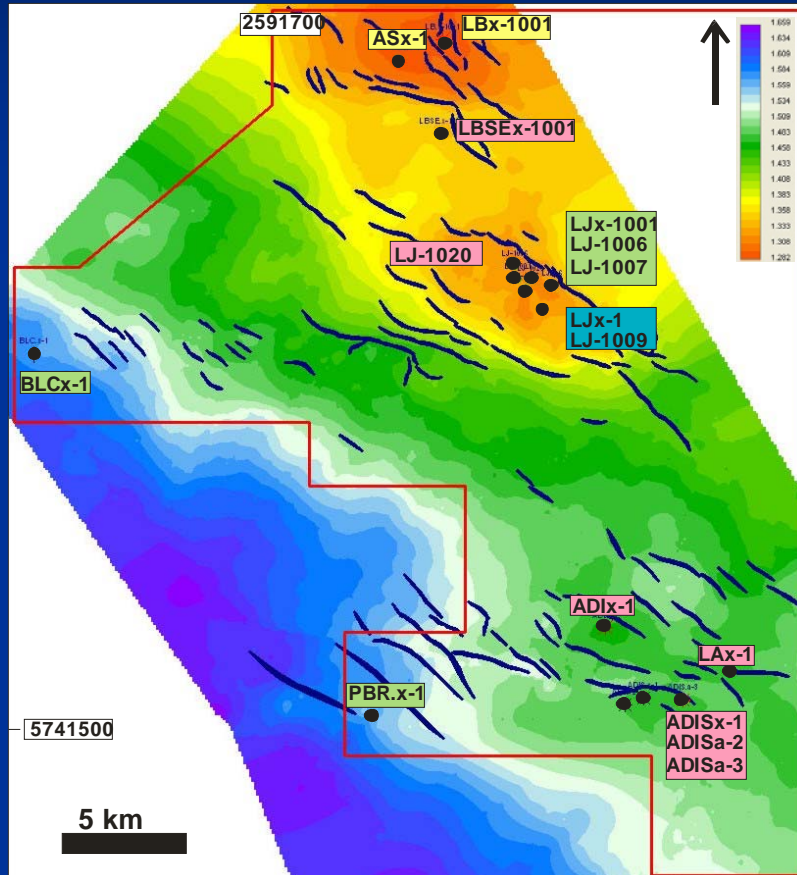
● Vaca Muerta

■ Los Molles 1

▲ Los Molles 2

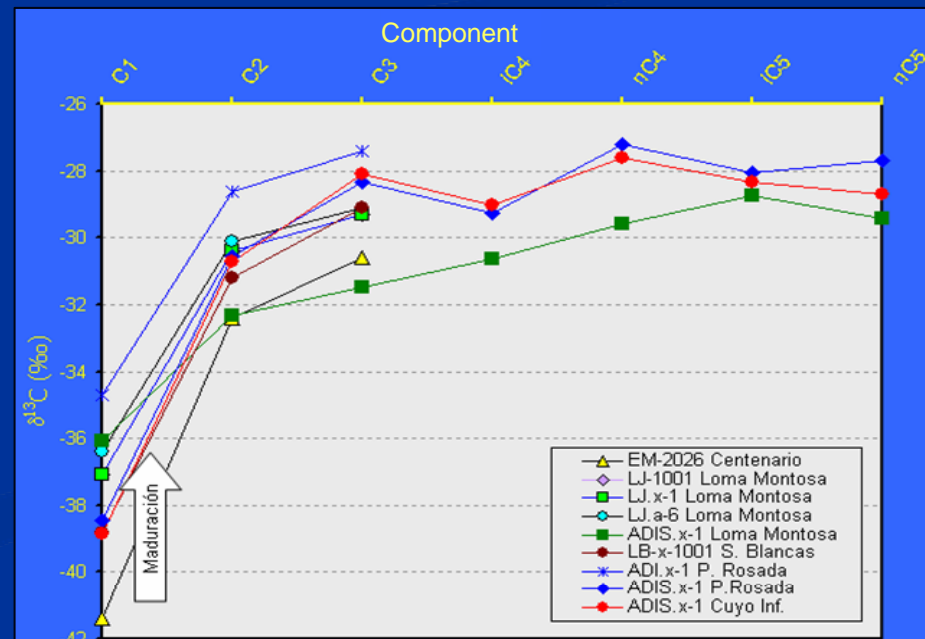
Gas Geochemistry

Control Points

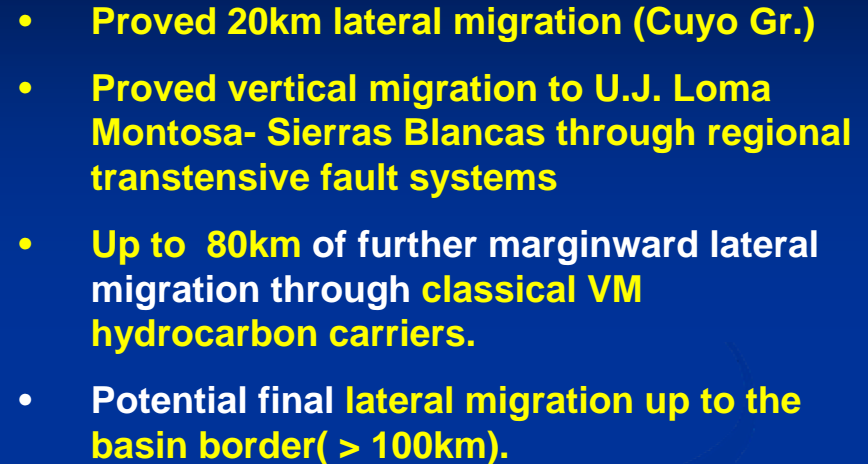


Occurrence of gas in G. Cuyo, Sas. Blancas and L. Montosa

- Heterogeneous molar and isotope compositions indicating multiple sources and wide ranges of thermal maturity.
- Gases of different maturation and migration events (Ro equiv. ~ 0.7-2.0%), both from Los Molles and Vaca Muerta sources.
- Deep reservoirs gases are linked to Los Molles generation, while shallower to mixed contributions.



Migration model:



Conclusions

- A **lateral migration drainage model** is proposed for the hydrocarbon sourced from **Los Molles shales in the Catriel platform**,
- **Identification of a natural carrier** with proved **good petrophysical properties** at critical burial depths.
- **Geochemical characterization of oil and gas** discoveries bearing the signature of **Los Molles source rock** in the **braid delta deposits** and overlaying **Sierras Blancas-Loma Montosa reservoirs**.
- A **deep gas play** developed along a **150km long hinge line**, given by the **pinch-out of braid delta deposits** with porosity preserving chlorite rims.
- This new deep gas play has potential for **Tcf scale accumulation**, based on analogs and can **revitalize the exploration of a mature basin**.