

Local Long-Lived Basin-Margin Deformation and Multiple Petroleum System Occurrence in the Neuquen Basin, Argentina*

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Search and Discovery Article #11268 (2019)**

Posted December 16, 2019

*Adapted from oral presentation given at 2019 International Conference and Exhibition, Buenos Aires, Argentina, August 27-30, 2019

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Abstract

The field under study is located in the eastern region of the Neuquén Basin, north of a fault zone that separates this part of the basin from the North Patagonian Massif. The field has a depleted shallow oil and gas pool that accumulated ~64 MMboe from conventional reservoirs and a currently developing deep tight-gas pool that has already produced +42 MMboe. The structural and stratigraphic configuration around this multi-reservoir oil and gas field was investigated to understand the controls of prolonged basin-boundary fault zone reactivation on the local development of vertically stacked, independent, petroleum systems. 2D and 3D seismic surveys of varying quality, in conjunction with +200 exploration and production well datasets, were used to create structural cross sections, reservoir and source rock maps and hydrocarbon generation and expulsion models. From south to north the study area has three well-defined structural domains: (1) a rigid basement block covered by a reduced sedimentary section that thins to the south, (2) a thick and narrow depocenter bounded by high-angle faults, and (3) a highly subsiding, but little deformed, downthrown block capable of collecting hydrocarbons generated away from the field area or from local deep-seated source pods. Triassic to Jurassic rift and post-rift tectonic phases allowed the deposition of source rock and reservoir facies resulting in a tight-gas accumulation belonging to the Los Molles-Lajas(!) petroleum system. Cretaceous fault reactivation and basin-margin exhumation-controlled sediment provenance, facies distribution and trap geometry of the shallower oil and gas bearing reservoirs related to the Vaca Muerta-Quintuco(!) petroleum system. Observed structural and stratigraphic variations between faulted blocks and petroleum system modelling results indicates that long-lived fault zone reactivation and footwall sediment supply allowed the local accumulation of source rock facies far from basin center areas as

well as the stacking of multiple reservoir levels in the sedimentary cover. Similar configurations can be found in other parts of the Neuquen Basin to search for new exploration opportunities.

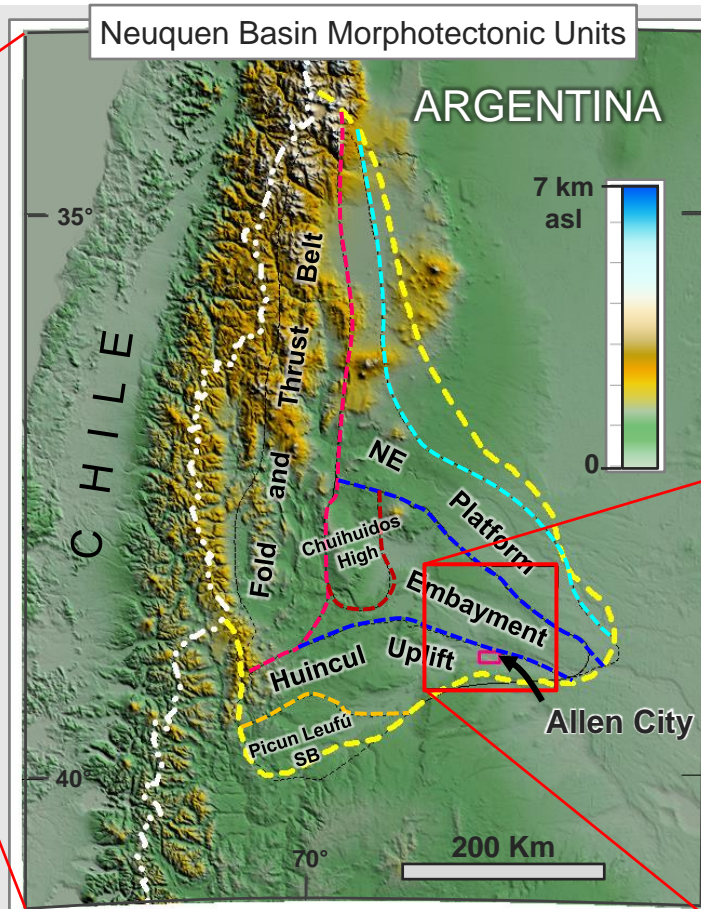
An aerial photograph of an oil field in the Neuquén Basin, Argentina. The image shows a large area of green vegetation, a road, and a tall oil rig. In the foreground, there are several white storage tanks and a small body of water.

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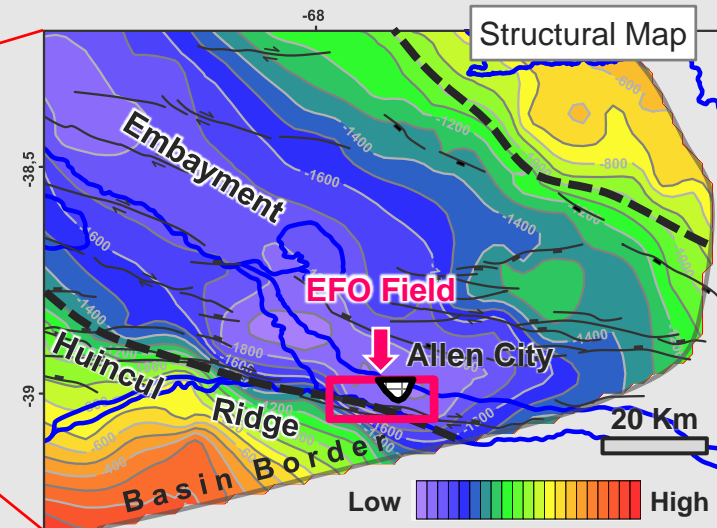


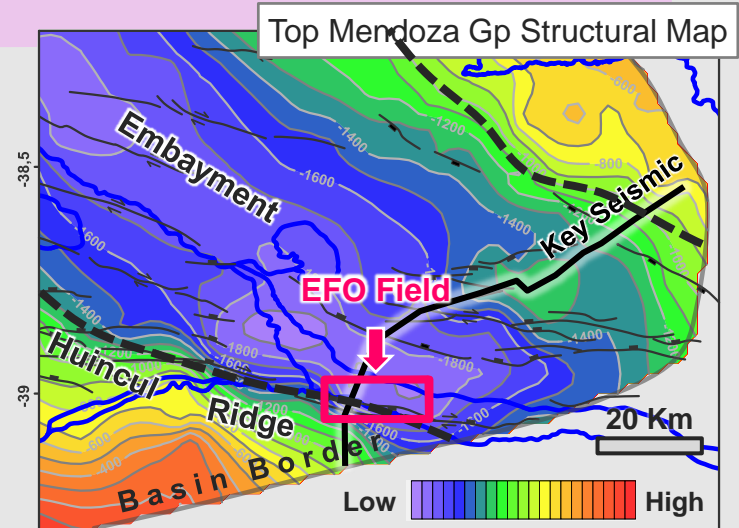
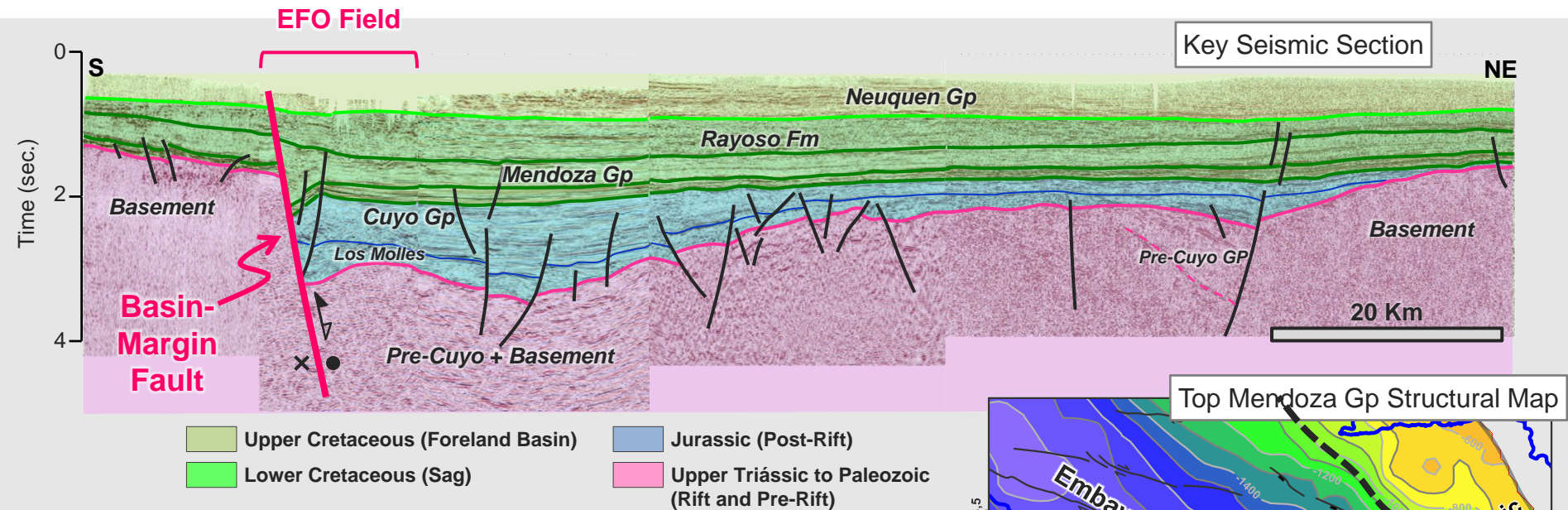
The study area is located in the eastern sector of the Neuquén Basin, south of Allen city.



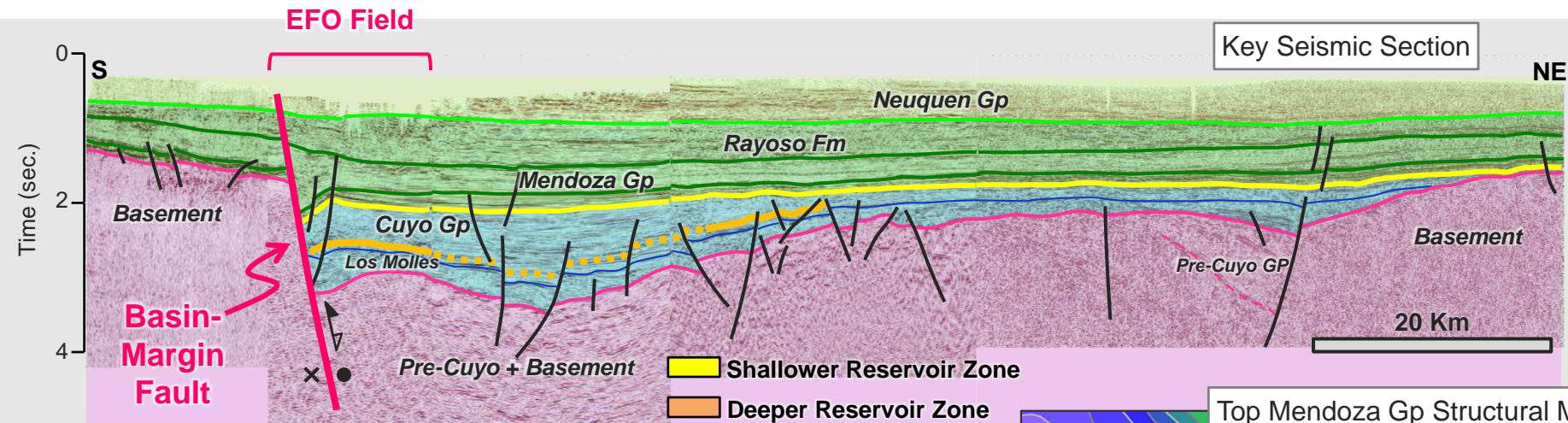
Main geological features:

- ✓ **Huincul Ridge:** +200 km long, ENE-WSW trending arch with contractional and strike-slip structures.
- ✓ **Embayment:** +5 km thick, NW-SE oriented depocenter that contains two important source rock intervals.

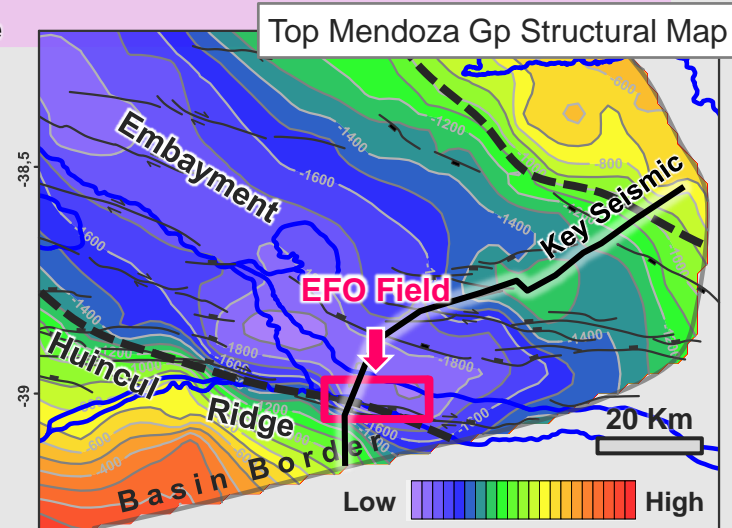


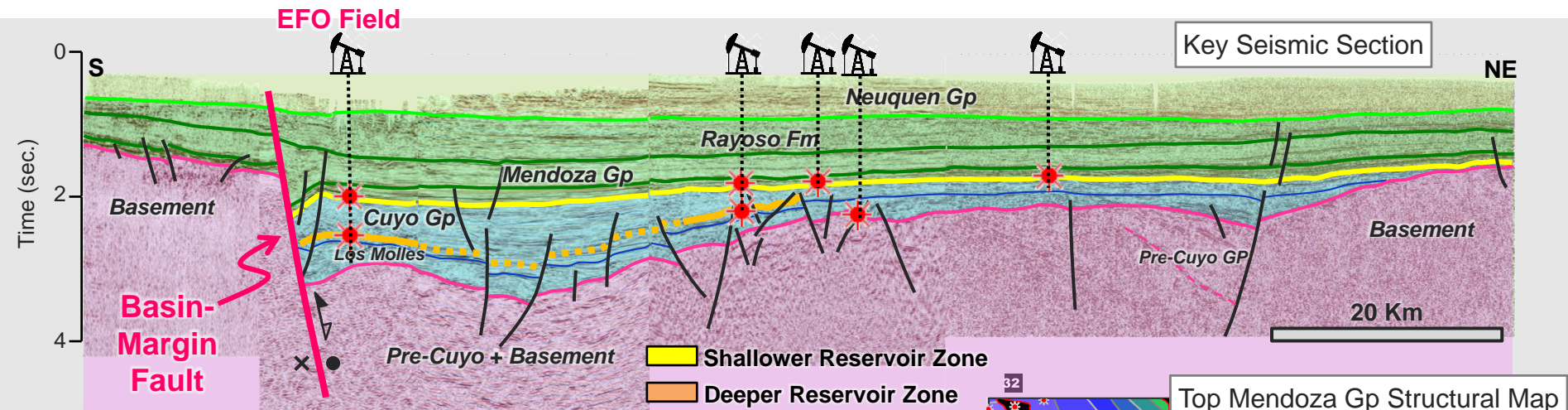


- ✓ Asymmetric basin fill that thickens to the south.
- ✓ High-angle basin-margin fault +3 Km displacement.
- ✓ Strong fault-controlled sedimentary thickness variation.



- ✓ **Shallower Reservoir Zone:** a more or less continuous stratigraphic interval made of near shore sandstones and limestones (Quintuco Fm) and continental sandstones (Sierras Blancas and Punta Rosada Fms).
- ✓ **Deeper Reservoir Zone:** near shore, mostly tight, sandstones of the Lower Cuyo Gp.

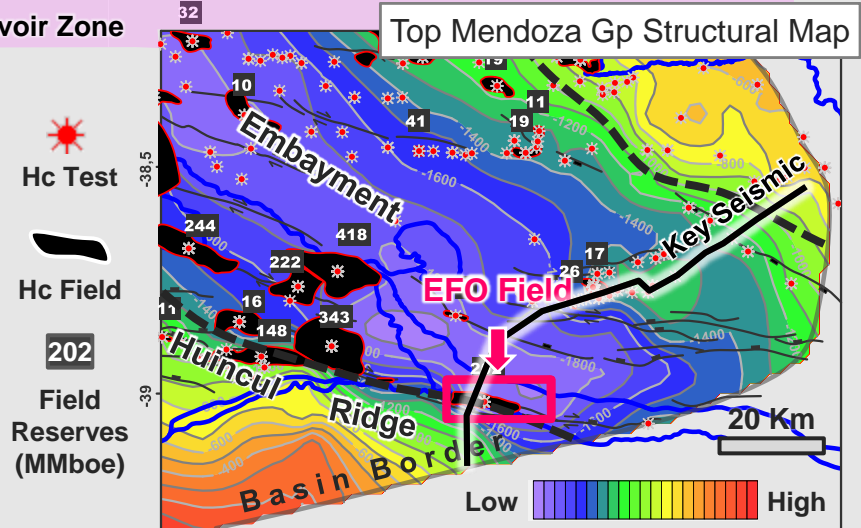




Traps types:

- ✓ Structural closures near faults and lineaments.
- ✓ Continuous low permeability sandstones of the Lajas Fm.

Biggest fields are towards the southern flank of the Embayment area.

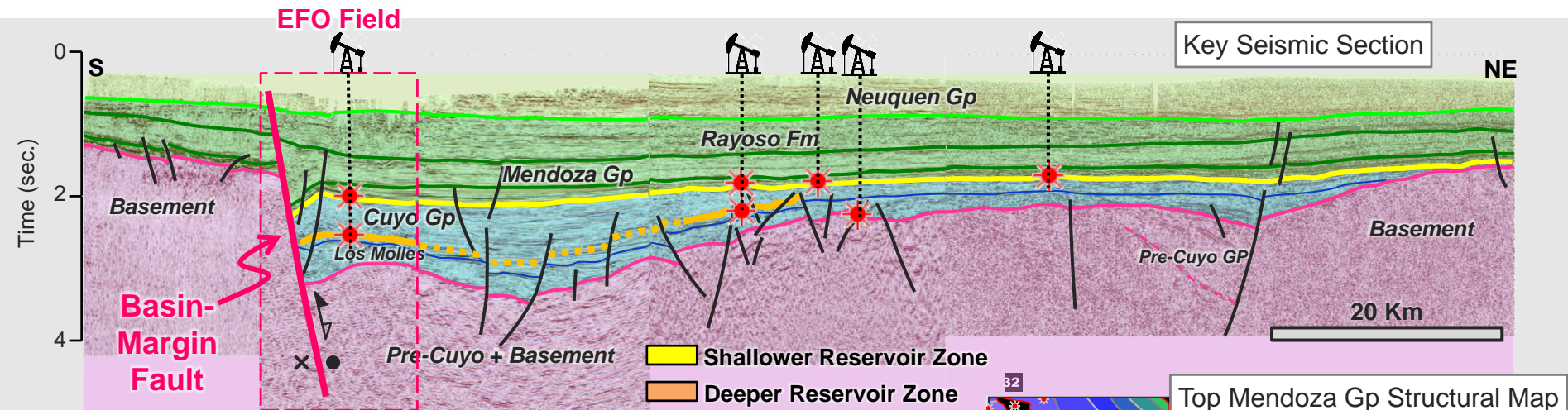


Hc Test

Hc Field

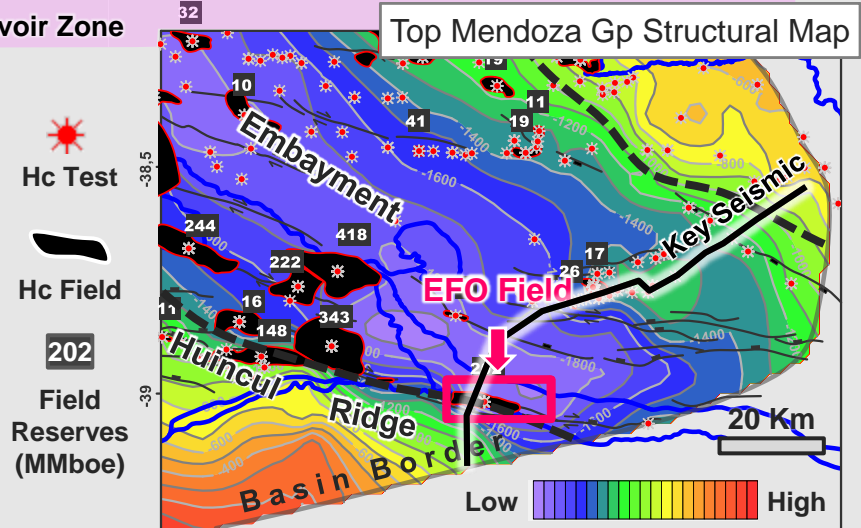
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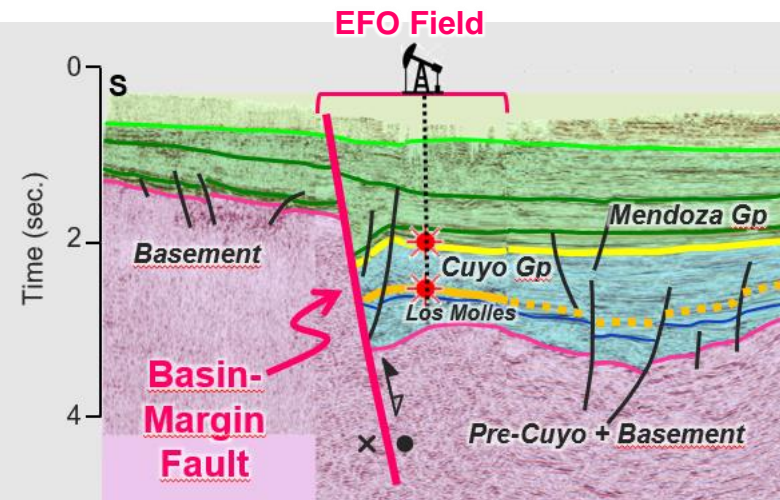
Field Reserves (MMboe)



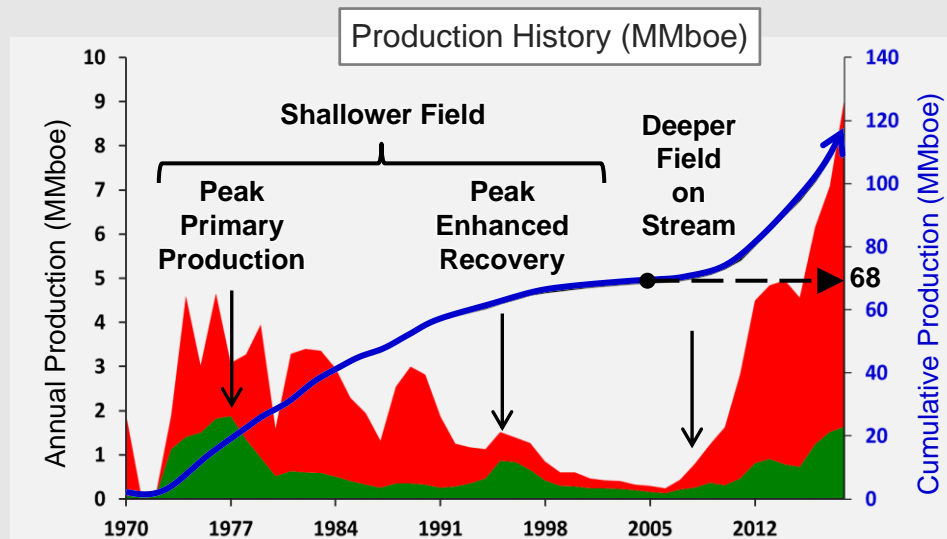
The objective of this study is to analyze the effects of repeated fault zone reactivation on:

- Field trap formation
- Local reservoir and source rock distribution
- Hydrocarbon generation and migration

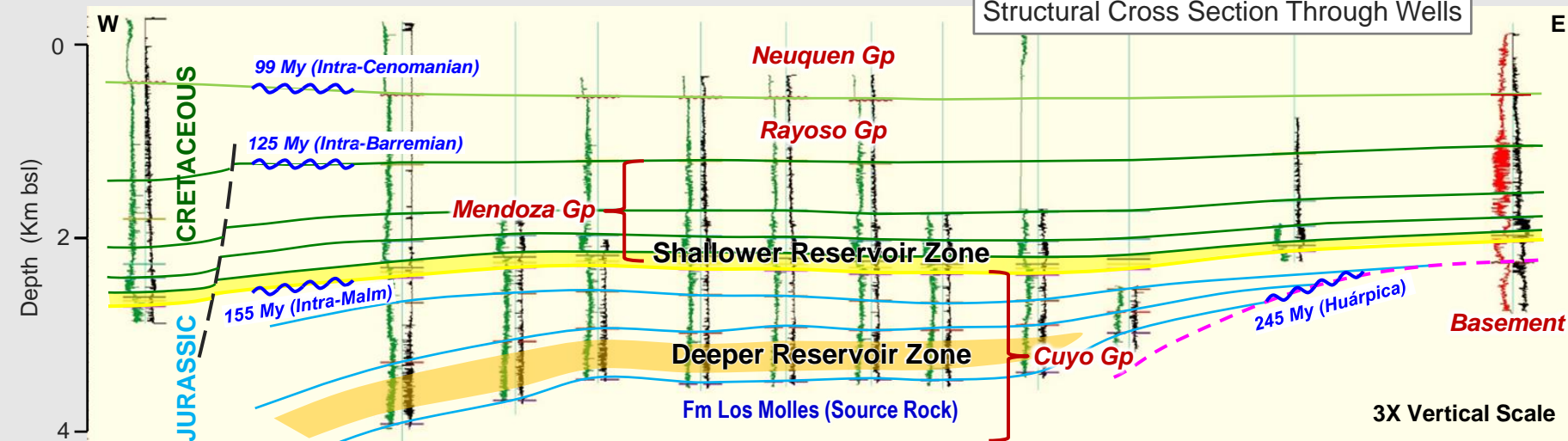




- ✓ O&G field discovered in 1969 by YPF.
- ✓ +270 vertical and deviated wells.
- ✓ Productive from:
 - 1) A shallower reservoir zone (68 MMboe).
 - 2) A deeper tight gas reservoir zone (66 MMboe EUR).



Structural Cross Section Through Wells



Neuquen Gp: alluvial and fluvial sandstones and conglomerates.

Rayoso Gp: fluvial and playa lake sandstones and siltstones.

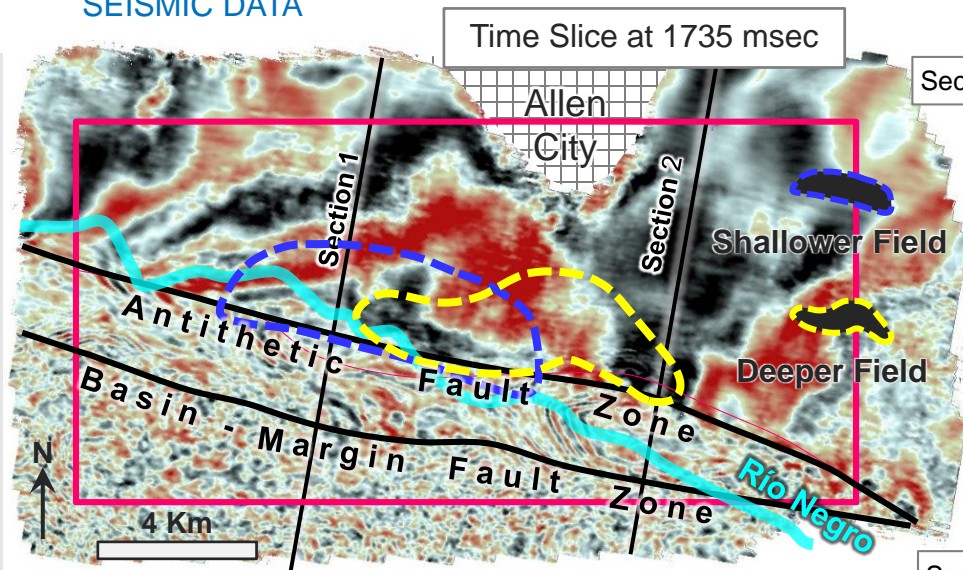
Mendoza Gp: near-shore sandstones, limestones and shales.

Cuyo Gp: deep marine shales with high TOC (Los Molles Fm) to near-shore, deltaic and fluvial sandstones and mudstones.

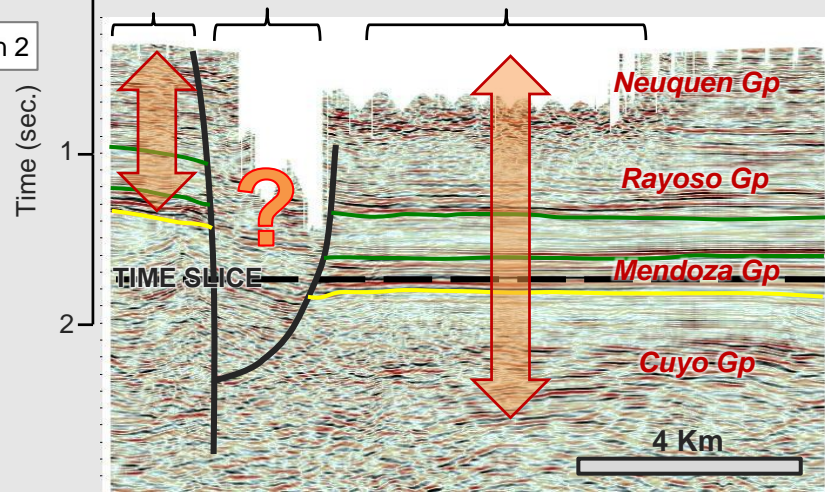
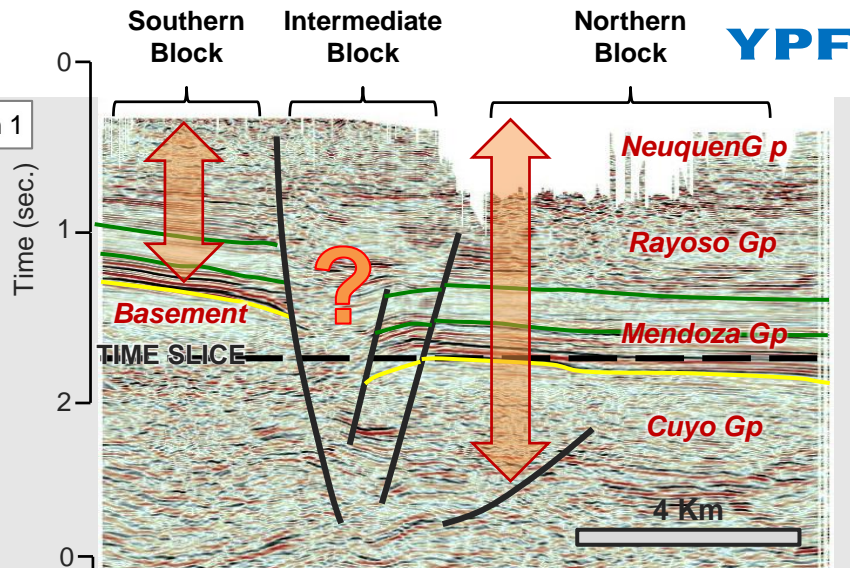
Pre-Cuyo Gp: continental clastic and volcanoclastic deposits.

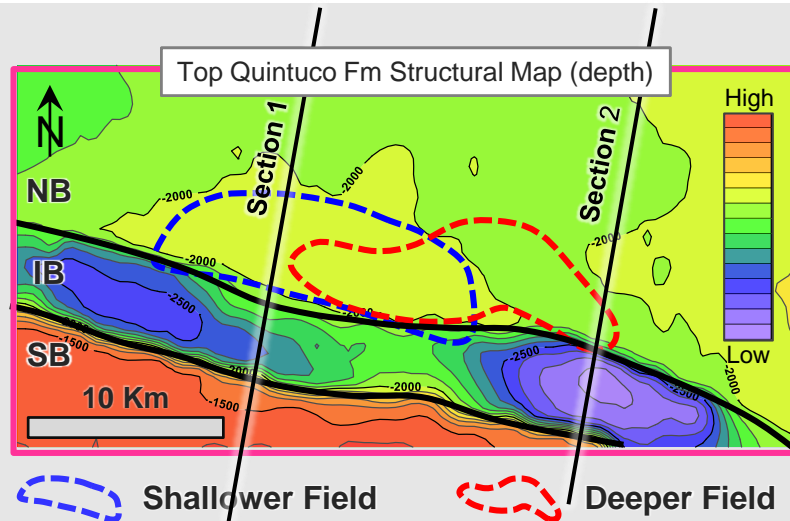
Basement: late Paleozoic to Triassic metamorphic and igneous rocks.

SEISMIC DATA

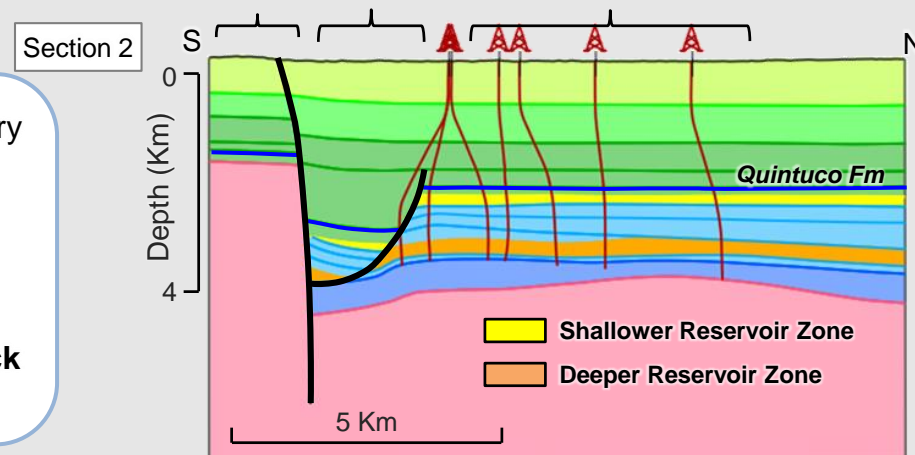
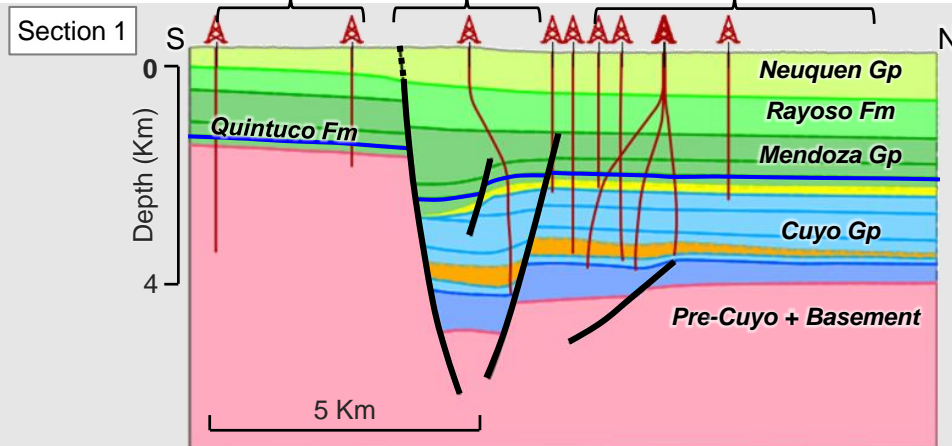


- ✓ An elevated **southern block** with a reduced sedimentary cover.
- ✓ A narrow, structurally complex, fault-bounded **intermediate block**.
- ✓ A tectonically depressed, little deformed, **northern block** covered by a thick and continuous sedimentary fill.

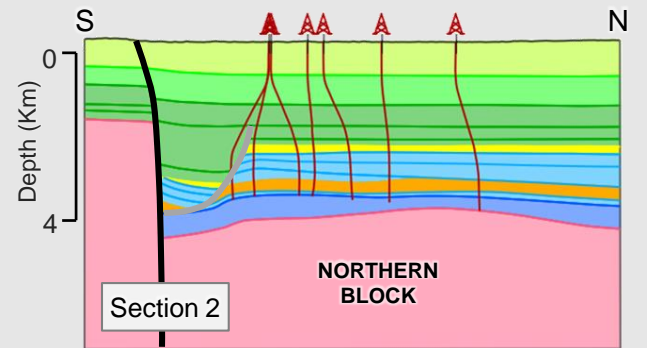
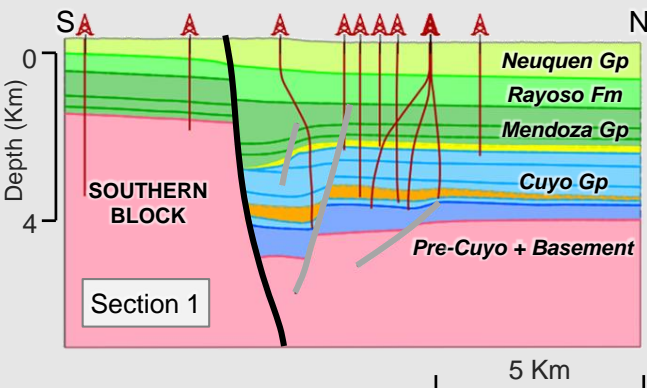




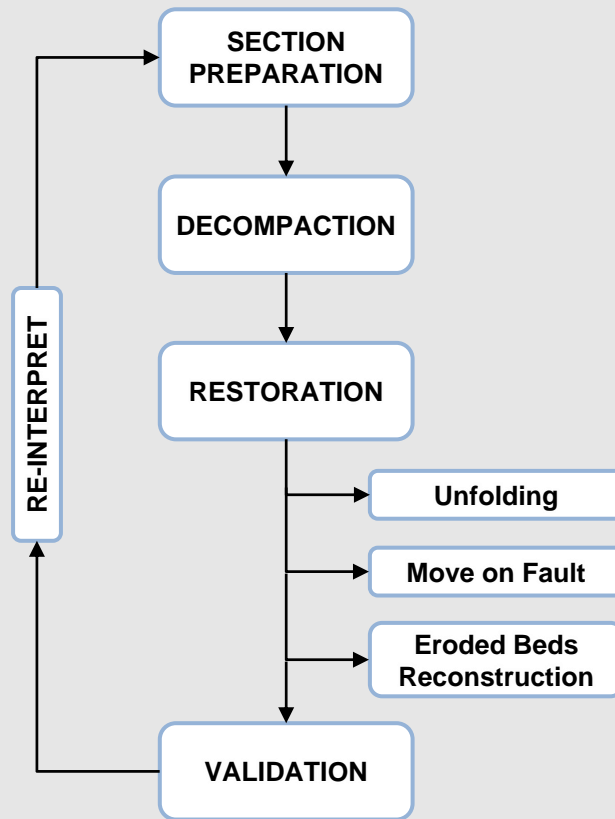
- ✓ An elevated **southern block** with a reduced sedimentary cover.
- ✓ A narrow, structurally complex, fault-bounded **intermediate block**.
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- ✓ Decompaction of underlying deposits.
- ✓ Restauration to pre-deformation shapes.



PRESENT DAY

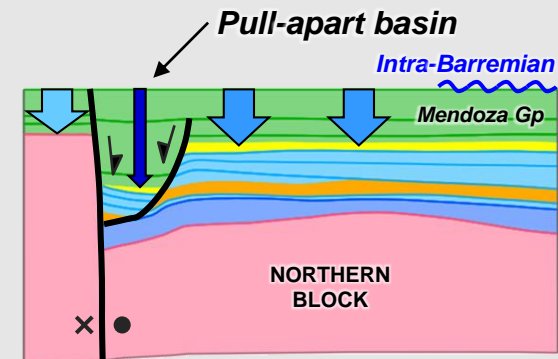
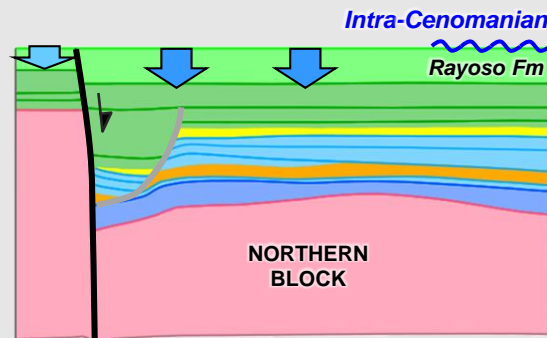
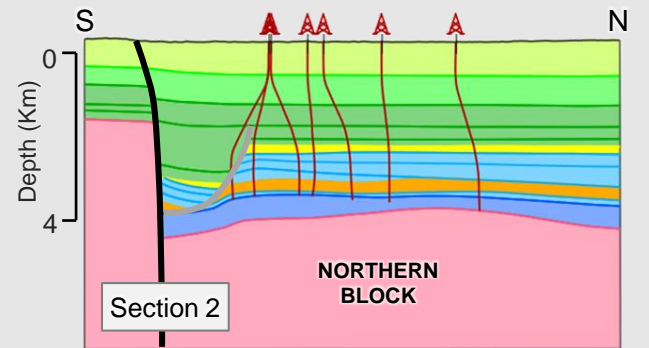
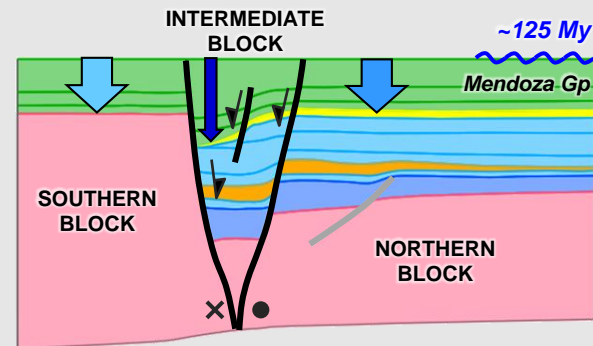
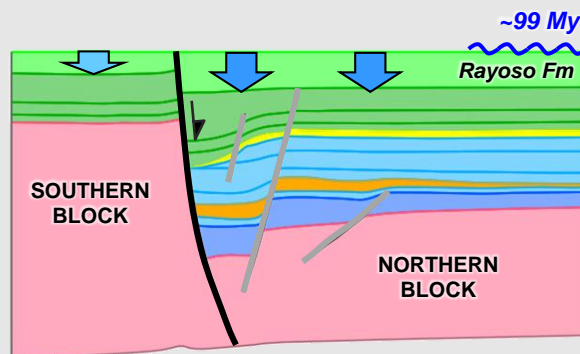
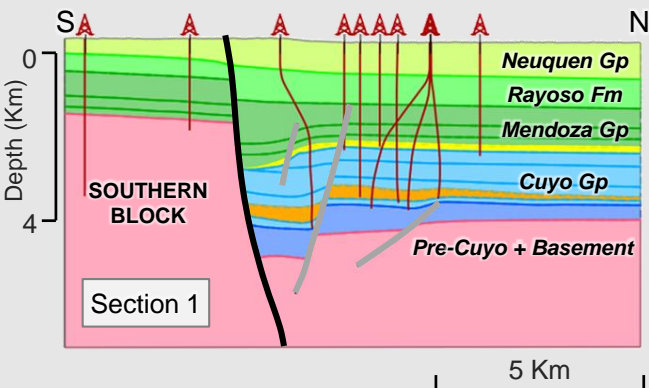


NOTE: No isostatic nor paleo-bathymetric effects have been considered

- ✓ Decompression of underlying deposits.
- ✓ Restoration to pre-deformation shapes.

- ✓ Normal slip basin-margin fault reactivation.
- ✓ Higher subsidence rate in the downthrown block.

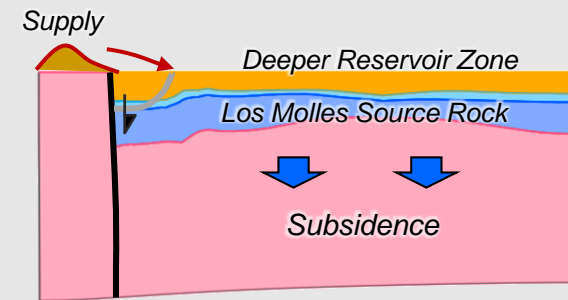
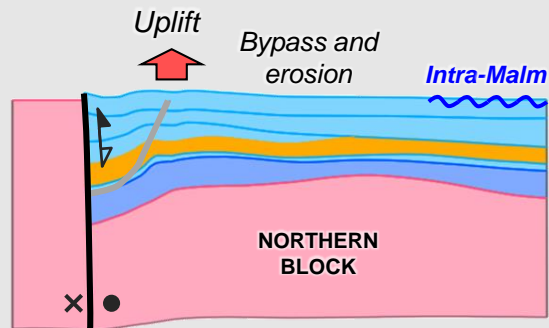
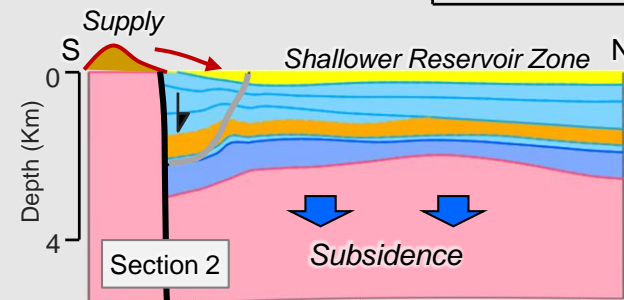
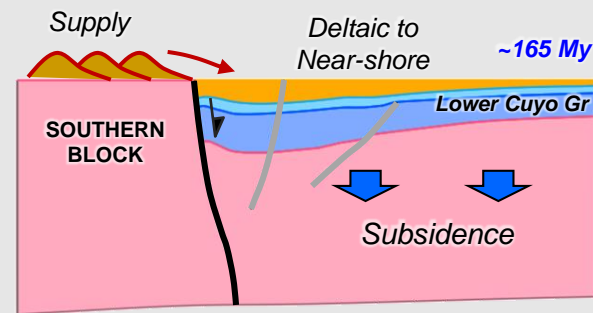
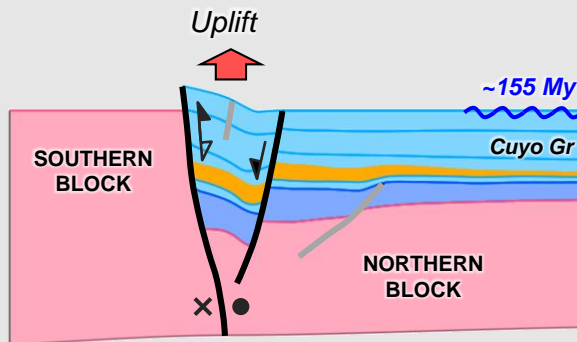
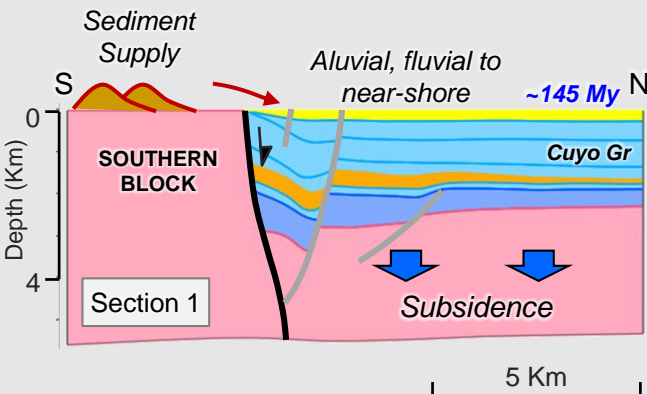
- ✓ Pull-apart basin related to a normal, strike-slip fault reactivation.
- ✓ Localized higher subsidence rates.

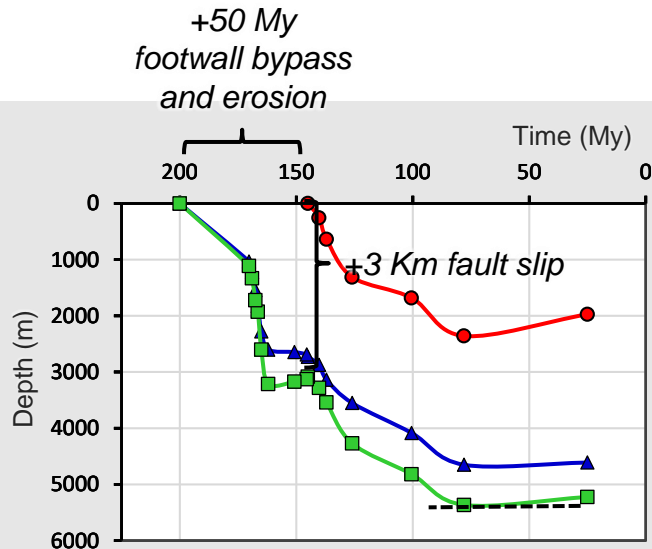
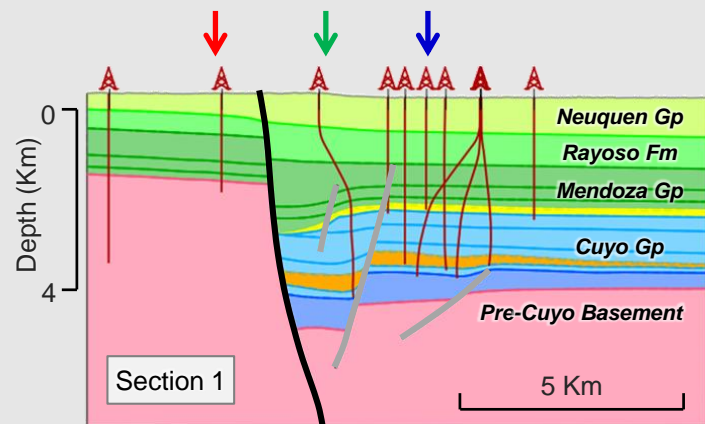


- ✓ Basin-margin normal faulting.
- ✓ Hangingwall subsidence and footwall sediment supply.

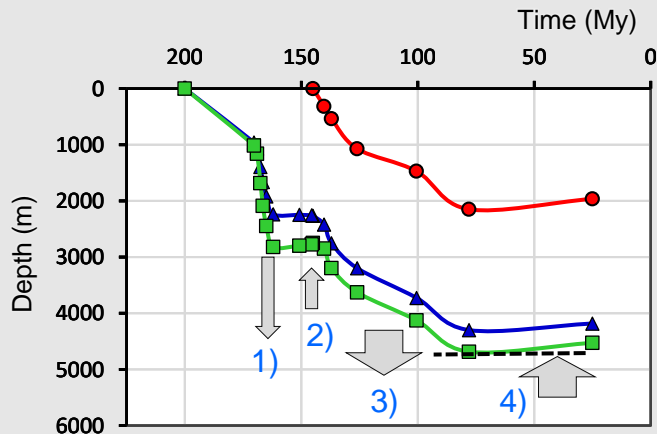
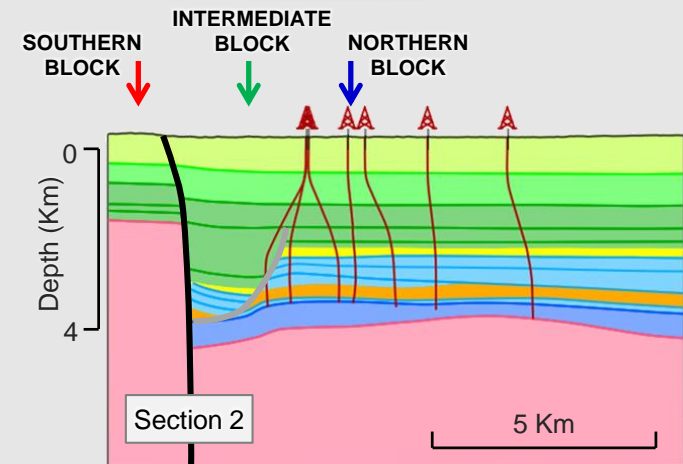
- ✓ Reverse strike-slip reactivation.
- ✓ Minor local uplift and folding against a rigid southern block (buttressing).

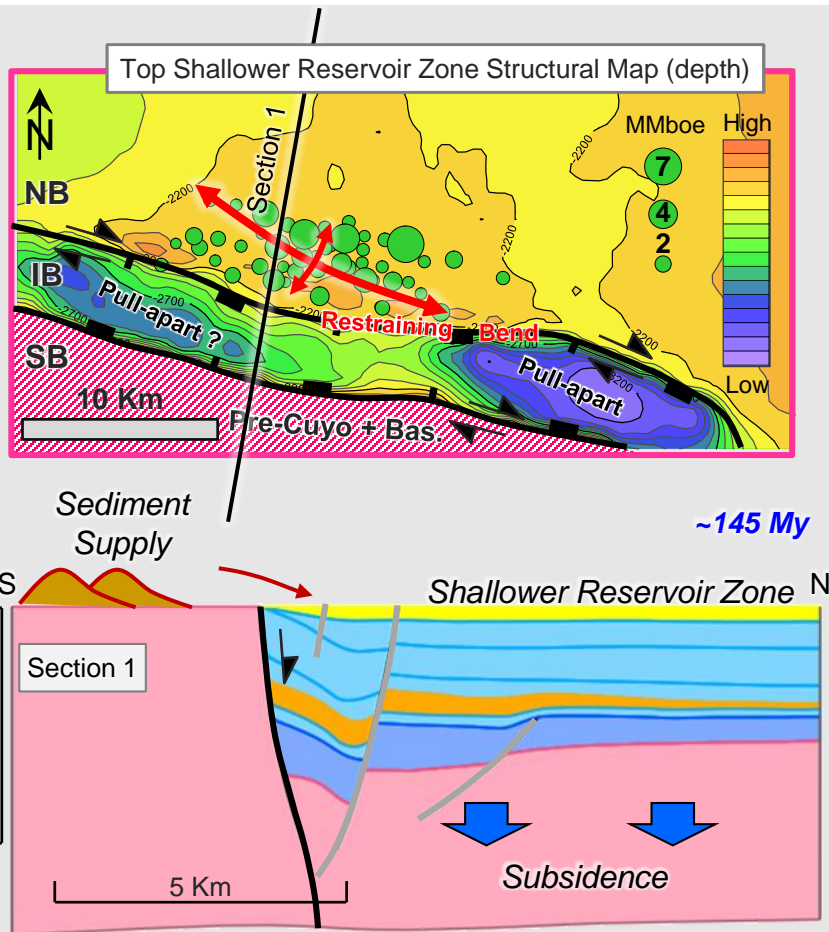
- ✓ Basin-margin normal faulting.
- ✓ Local sediment supply and accumulation of clastic deposits in the downthrown block.
- ✓ Source rock deposition.



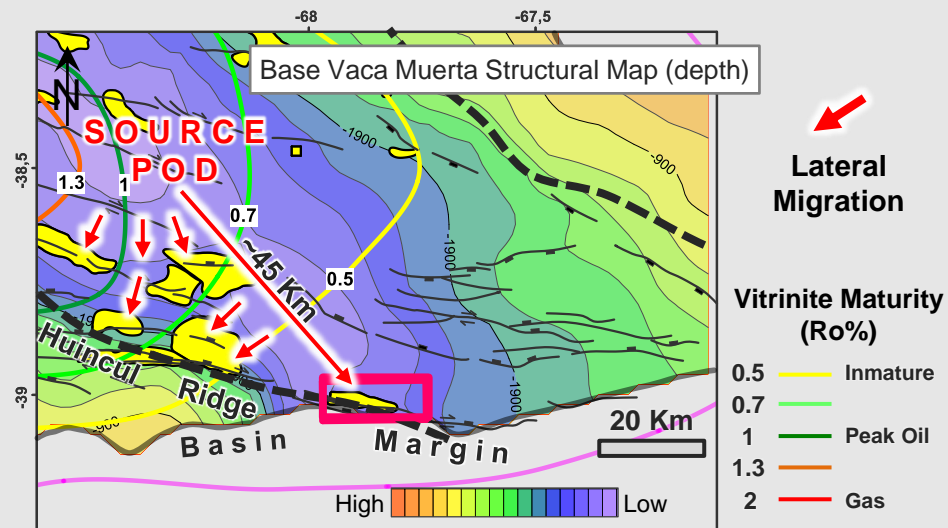


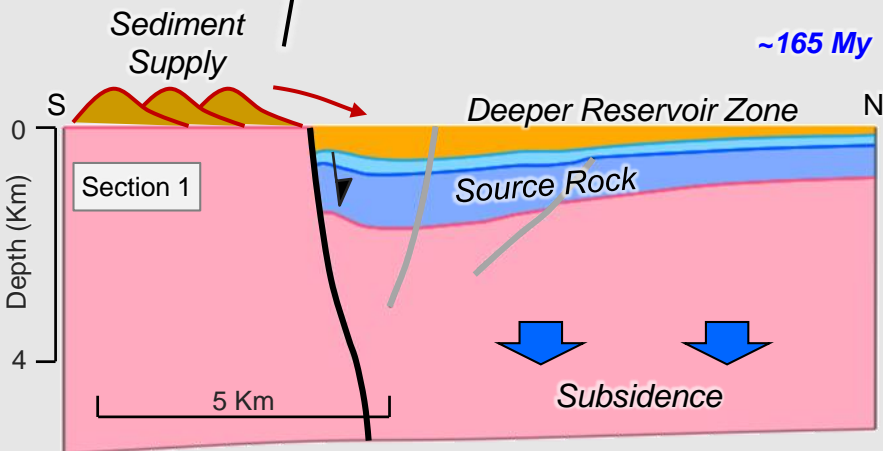
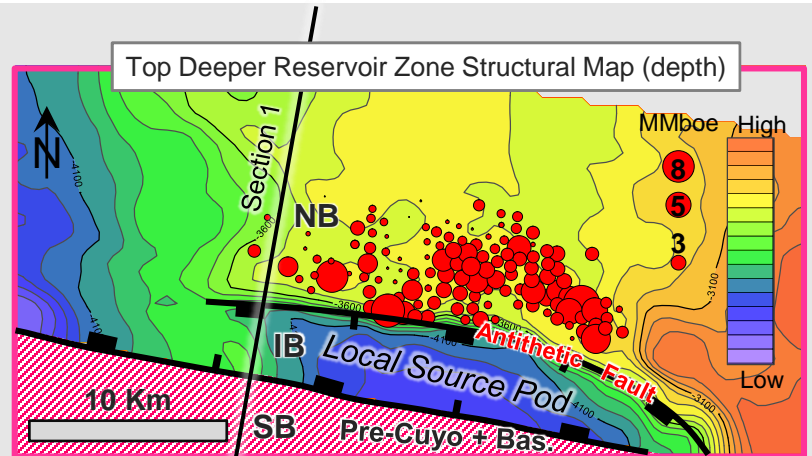
- 1) High, fault-controlled, subsidence rate.
- 2) Local fault reverse reactivation and uplift.
- 3) Generalized subsidence and pull-apart basin formation.
- 4) Regional exhumation and probable basin-margin fault reactivation.



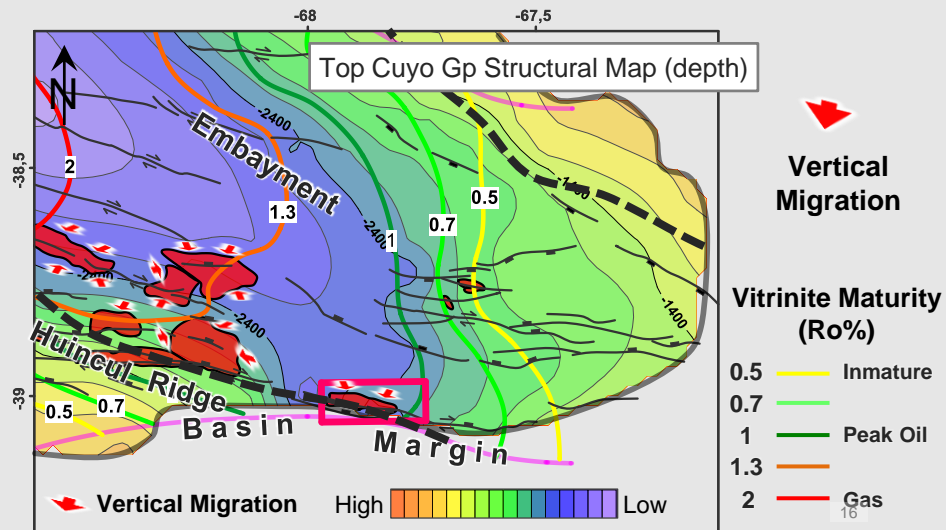


- ✓ **Footwall anticline trap** related to a restraining bend along a dextral strike-slip fault.
- ✓ **Reservoirs** sourced from a southern sediment supply area.
- ✓ **Hydrocarbons charged laterally** from a distant Vaca Muerta source pod.

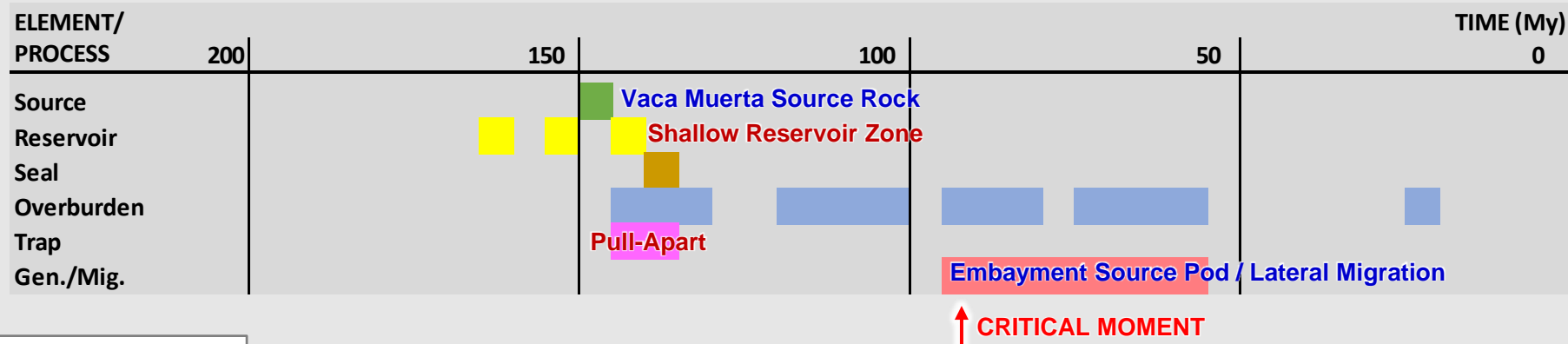




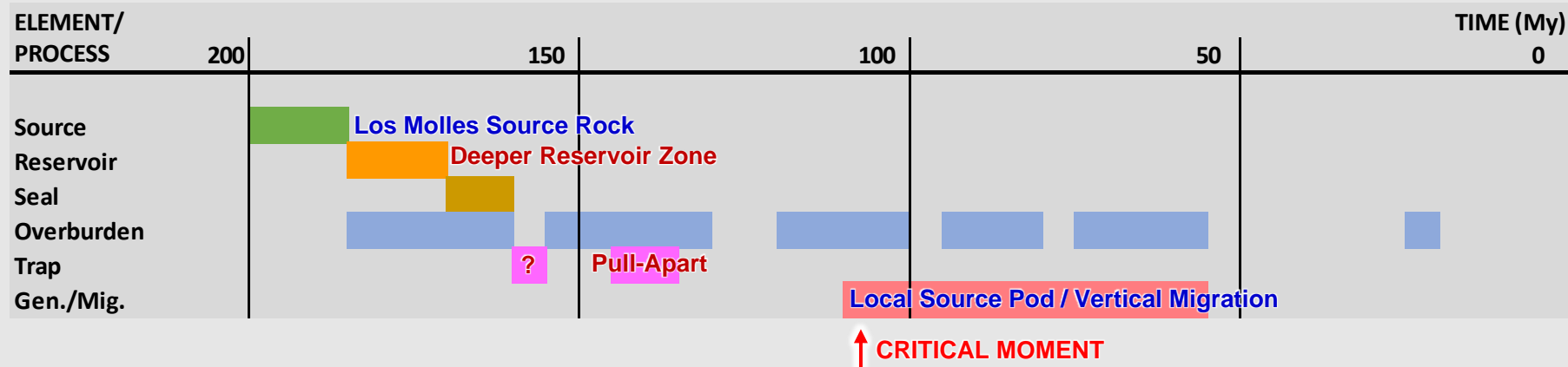
- ✓ **Continuous tight gas trap** formed in the footwall block of an antithetic normal fault.
- ✓ **Reservoir** sourced from a southern sediment supply area.
- ✓ **Hydrocarbons charged vertically** from a local Los Molles source pod.



SHALLOWER FIELD



DEEPER FIELD



- 1) Repeated fault reactivation in the EFO field controlled trap formation, multiple reservoir stacking and local source rock deposition and maturation.
- 2) The fault-bounded Intermediate Block took up most of the deformation, protecting the trap integrity of both the shallower and deeper fields.
- 3) The **shallower field** is characterized by:
 - ✓ a footwall anticline trap related to a restraining bend along a dextral strike-slip fault zone.
 - ✓ multiple clastic reservoir levels sourced by a local sediment supply area.
 - ✓ a +45 km lateral migration from a Vaca Muerta source pod.
 - ✓ a favorable timing relationship between trap formation and hydrocarbon migration.
- 4) The **deeper field** is characterized by:
 - ✓ a continuous trap type located in the footwall block of an antithetic fault complex.
 - ✓ a tight reservoir zone sourced by a local sediment supply area.
 - ✓ a local deep seated, gas prone source pod.
 - ✓ Short-distance, vertical migration paths.