PSCharacterization Of Rayoso Formation for Underground Natural Gas Storage in Cupen, Neuquen Basin*

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Search and Discovery Article #51618 (2019)**
Posted December 11, 2019

*Adapted from poster presentation given at 2019 International Conference and Exhibition, Buenos Aires, Argentina, August 27-30, 2019
 DOI:10.1306/51618Suarez2019

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Abstract

Objective: The underground natural gas storage (UNGS) in this project involves a conversion of a depleted gas field from production to storage, taking advantage of existing wells, gathering systems, pipeline connections and its location close to consumption centers. Depleted oil and natural gas reservoirs are the most commonly used underground storage sites because of their wide availability. This underground facility will allow us to balance a variable gas demand, storing gas in low demand periods (summer) and producing it in peak demand periods (winter) maintaining almost constant supply. The reservoir to be used for the UNGS consists of sandstones from Rayoso Formation that have produced all their economically recoverable gas, located at 500 meters depth, close to Cupén Mahuida area. Each storage type has its own physical characteristics (porosity, permeability, retention capability) and economics (site preparation and maintenance costs, deliverability rates, and cycling capability) which govern its feasibility. To evaluate if the depleted reservoir formation is readily capable of holding injected natural gas, a technical and economic pre-feasibility analysis was carried out. It is crucial to determine the capacity of the reservoir to hold natural gas for future use and the rate at which gas can be withdrawn (deliverability rate).Physical characteristics of the reservoir, seal and trap are equally important to define the aptness of the reservoir for UNGS. Procedures: A static model of Rayoso Formation was built for reservoir characterization. The geological model includes regional studies, outcrop observations, seismic interpretation (structural and stratigraphic), petrophysical analysis and production / pressures of the wells. Results: With this model, different scenarios are being simulated for volume rate injection / production in the area, also considering the existing infrastructure (existing wells, gathering systems, and pipeline connections. Conclusions: The physical characteristics of the reservoir became optimal for UNGS, as well as the structure and the seal. Two different levels had been identified as potential storage due to their wide extension and connectivity. The volume calculated with the static model agrees with the volume made through the material balance. In addition, the volume needed to inject/produce is appropriate to balance the demand of the field.

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CHARACTERIZATION OF RAYOSO FORMATION FOR UNDERGROUND GAS STORAGE IN CUPEN, NEUQUEN BASIN

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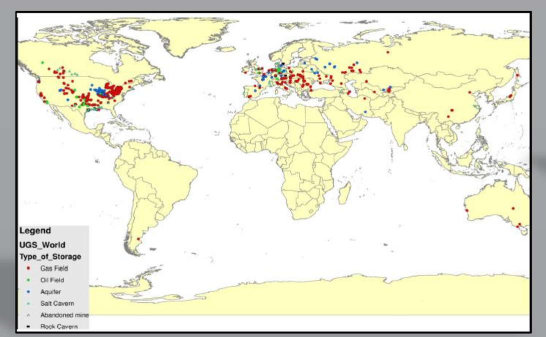
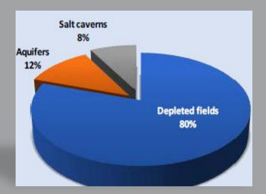
Underground Natural Gas Storage

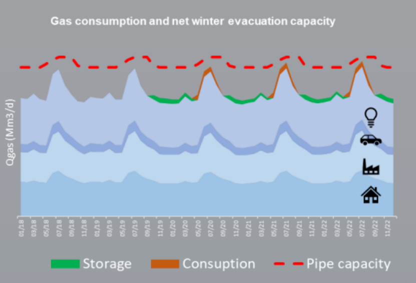
Storage in **depleted reservoirs**, **aquifers** or **caverns** with certain conditions of porosity and permeability to store the gas under pressure and in a gaseous state.
It is the **safest** way to accumulate **large volumes** of natural gas.
It is part of the gas evacuation system to respond to the needs of the Market.



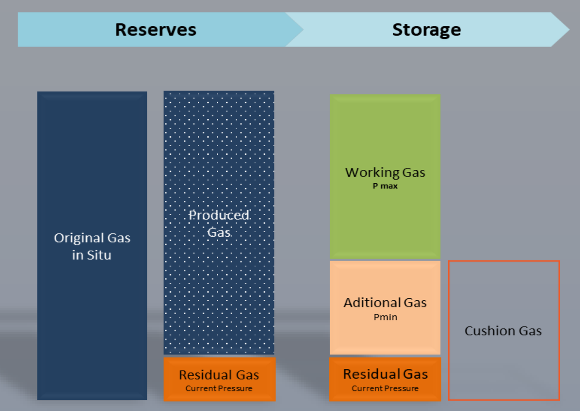


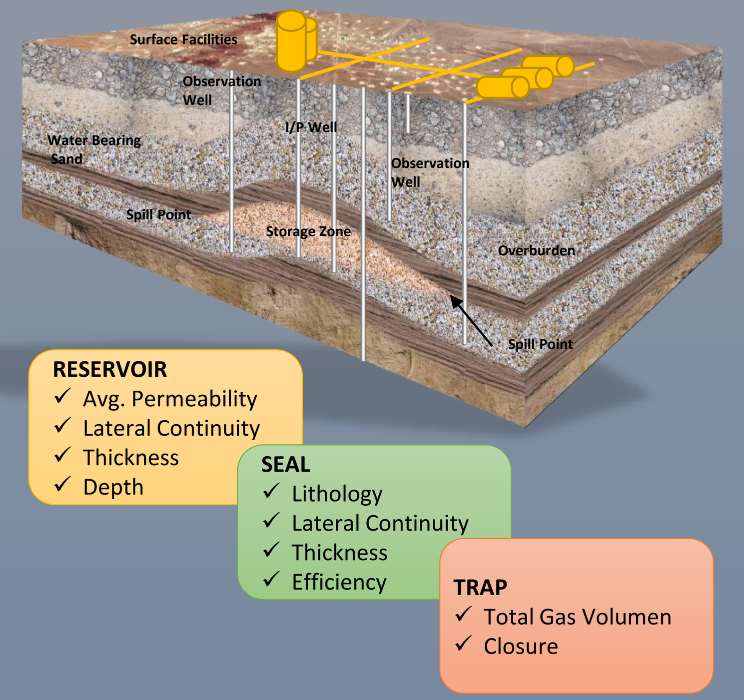
Objective

- Increase gas sales covering unsatisfied winter demand.
- Modulate gas production in producing fields by increasing the plateau and avoiding closures



Technical evaluation



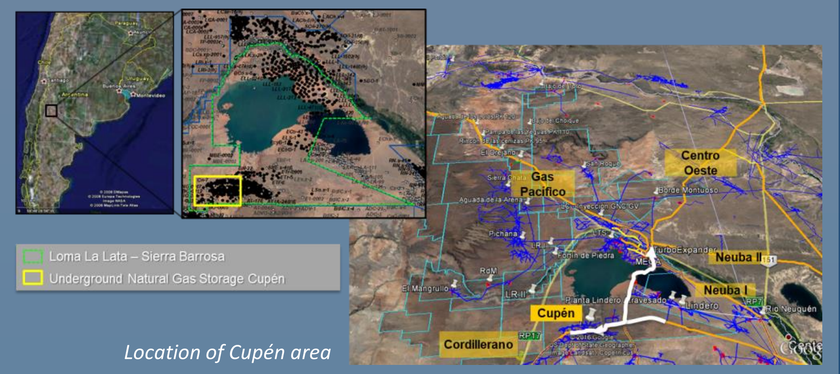


Cupén Field

The underground gas storage (UGS) in this project involves a conversion of a depleted gas field from production to storage, taking advantage of existing wells, gathering systems, pipeline connections and its location close to consumption centers.

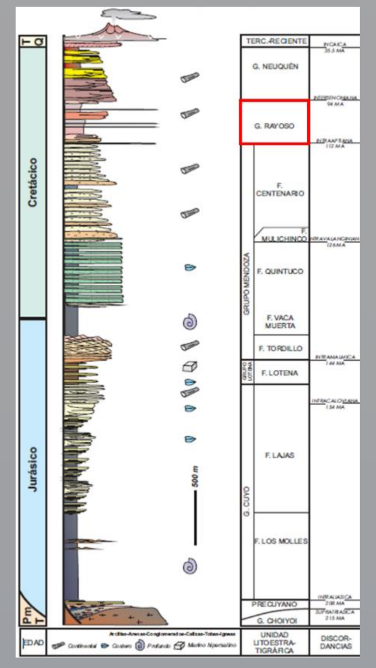
This underground facility will allow to balance a variable gas demand, storing gas in low demand periods (summer) and producing it in peak demand periods (winter) maintaining a near-constant supply.

The reservoir to be used for the UGS consists of sandstones from Rayoso Formation, located at 500 meters depth, close to Cupén field.



Location of Cupén area

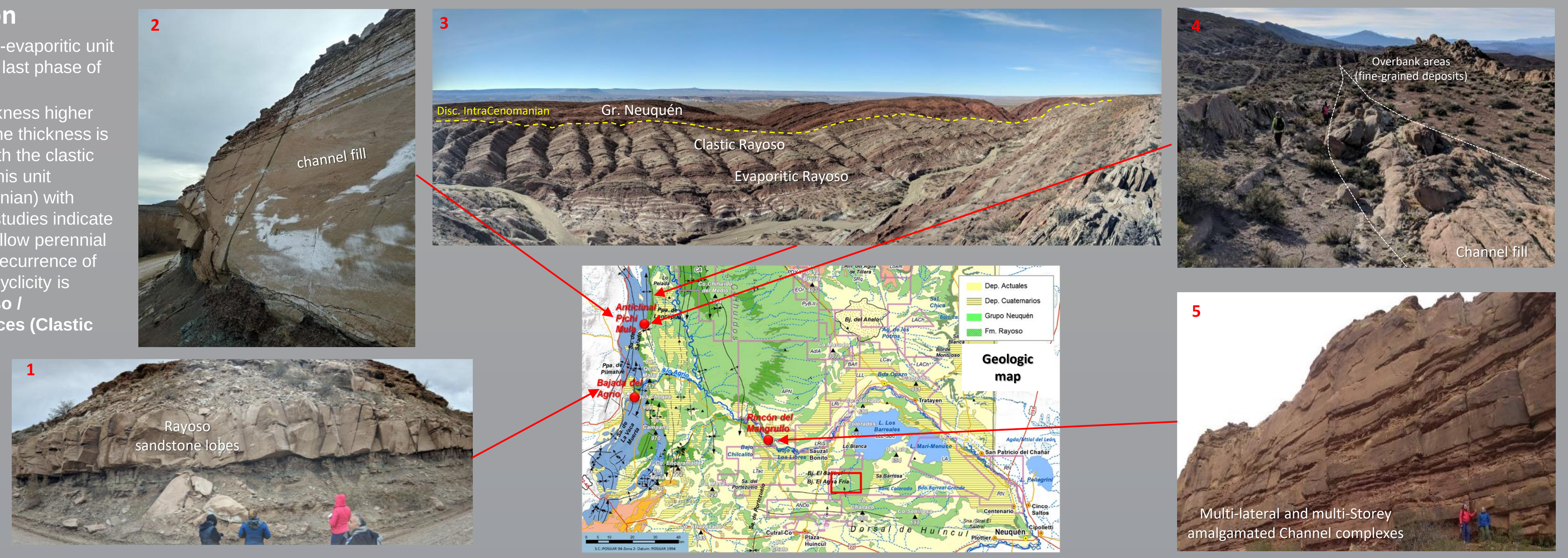
Geological Model: Rayoso Formation



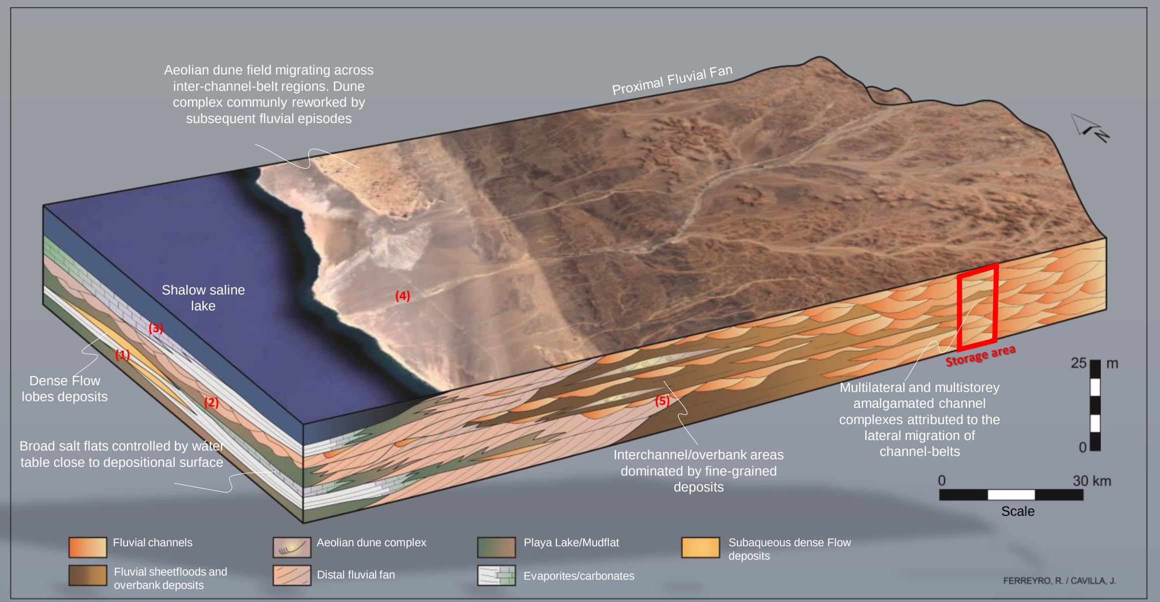
Brisson et al. - Embayment

The Rayoso Formation is an Early Cretaceous clastic-evaporitic unit accumulated in a continental environment, during the last phase of the post-rift stage of the Neuquén basin.

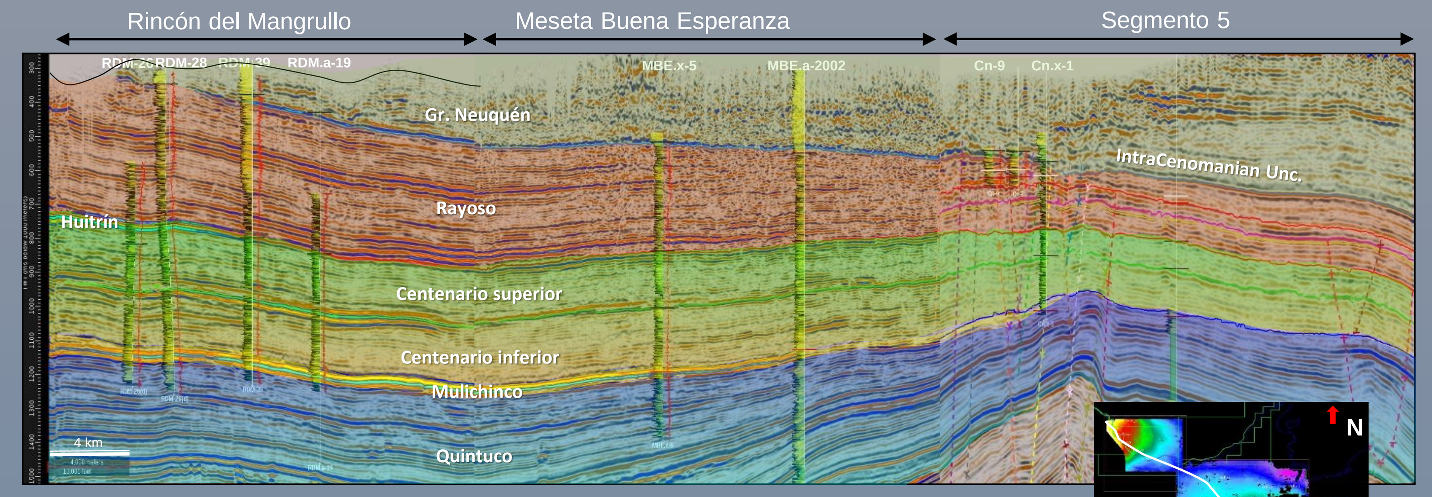
It covers more than 15.000 km^2 with a maximum thickness higher than 1200 m (Zavala et al., 2011). In the study area the thickness is greater than 300 m and it is found in direct contact with the clastic deposits of Centenario Formation. Towards the top, this unit truncates with an angular unconformity (IntraCenomanian) with Candeleros Formation of Neuquen Group. Regional studies indicate that the Rayoso Formation was accumulated in a shallow perennial lake environment of variable salinity, affected by the recurrence of humid and extremely arid periods alternated. These cyclicity is represented by **shaly sequences (Evaporitic Rayoso / Contractive System track) and the clastic sequences (Clastic Rayoso / Expansive System Track)**



Sandstone facies identified in the outcrop

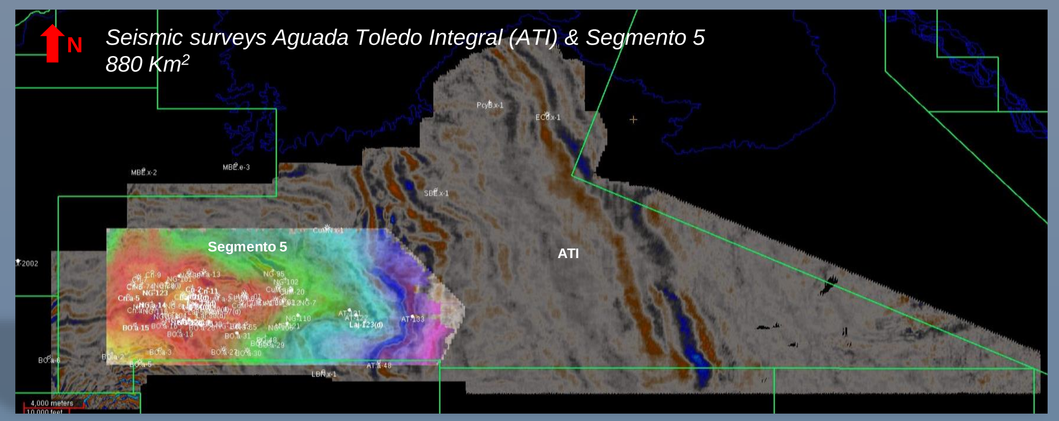


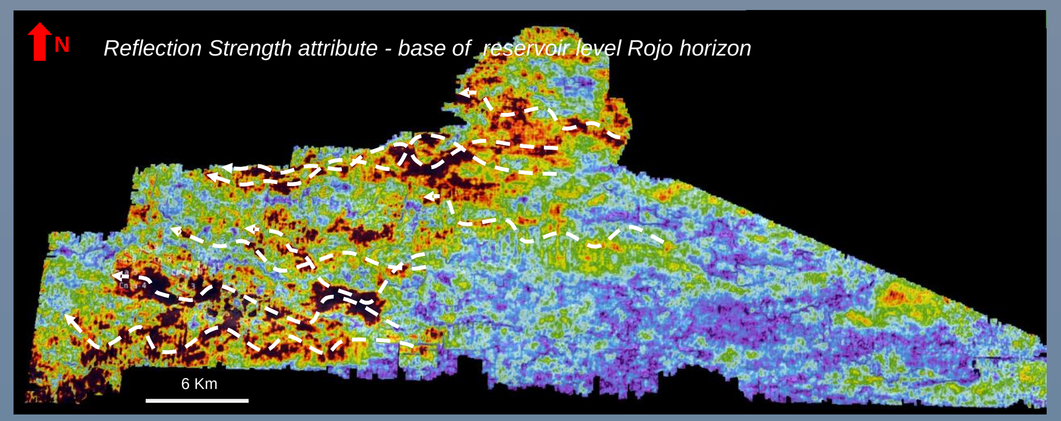
Seismic Interpretation

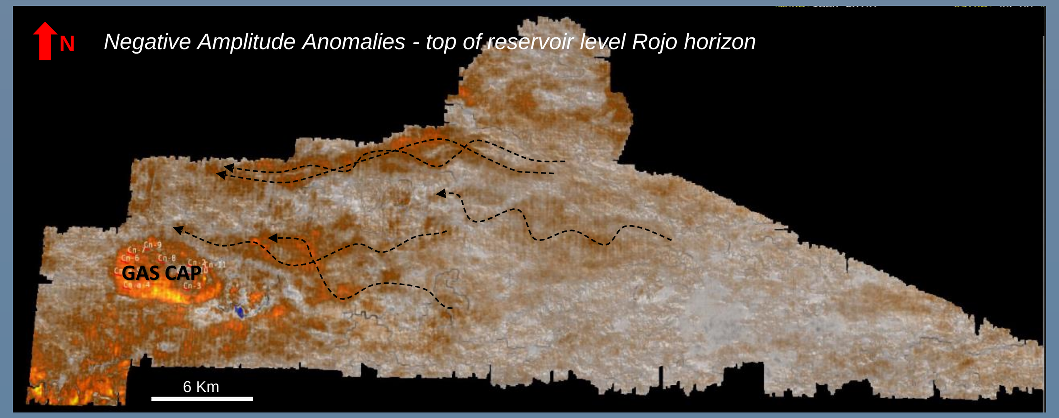


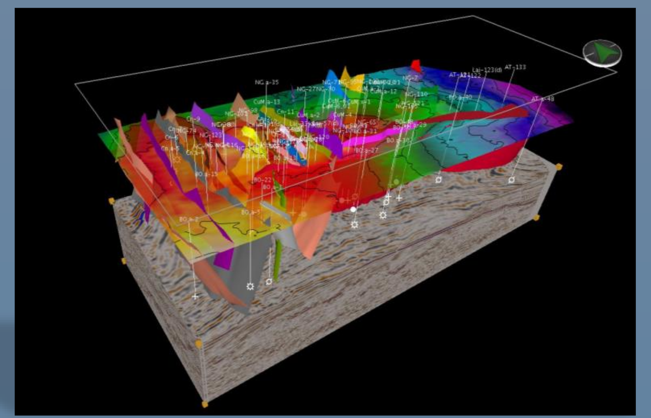
Regional seismic section of 67 km length that connects the outcrops of Rayoso Formation in the NW, with the subsurface deposits in the SE.

Four seismic surveys were used to perform seismic interpretation with different objectives. Segmento 5 to interpret horizons and faults, Aguada Toledo Integral (ATI) survey to obtain a clearer regional image of the **depositional geometric features**, Rincon del Mangrullo survey (RDM) to tie outcrops with subsurface deposits drilled by RDM wells and Meseta Buena Esperanza (MBE) to tie the outcrops with Segmento 5.
The geological structure correspond to a **shallow smooth anticline** of 15 Km^2 and 30 m of height, **intersected by several vertical N-S fractures with very low or almost non- vertical displacement**.
An angular unconformity (**IntraCenomanian**) separates the top of Rayoso Formation from Neuquén Group.



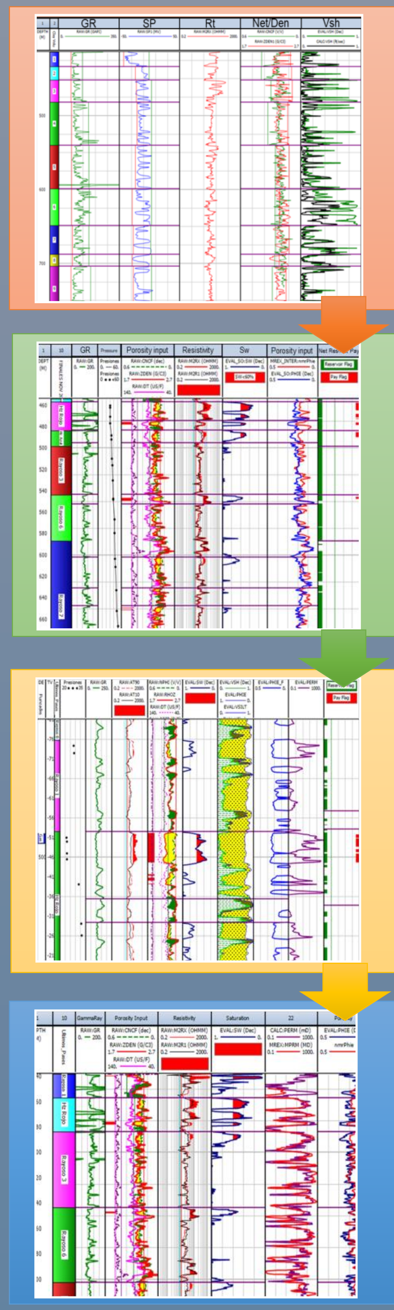






Fault plane distribution intersecting the surface representing the base of the Rojo horizon level.

Petrophysical Model



VSH from GR and DEN/NEU
Cut Off: <20% Net Sand

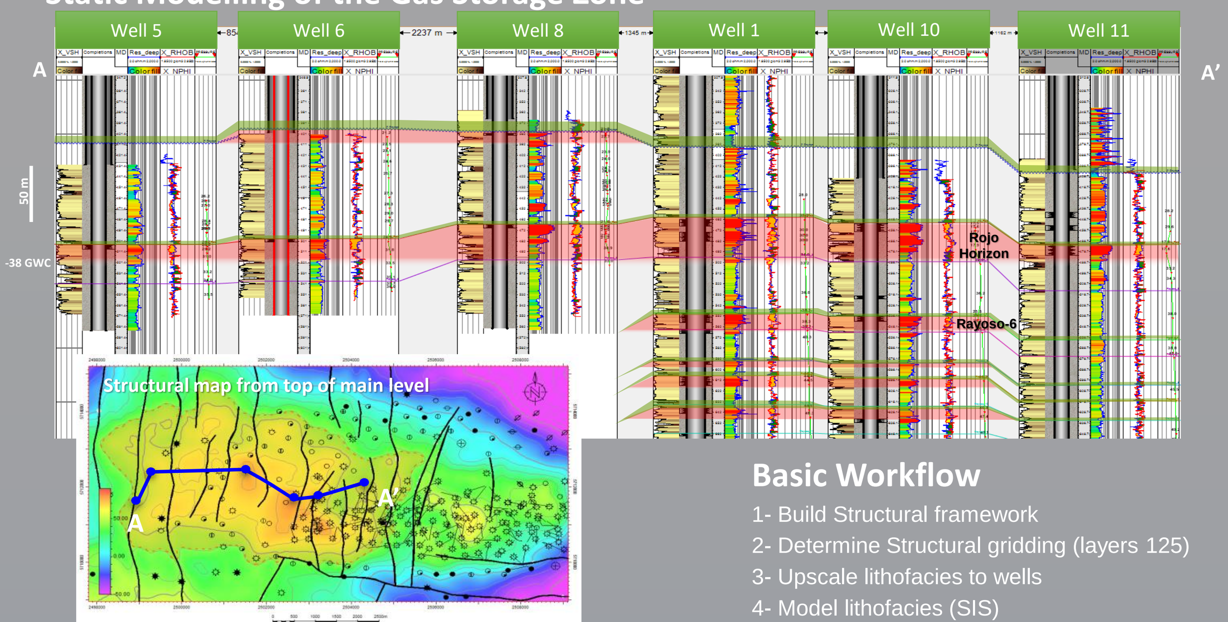
PHIE DEN and DT calibrated with parameters of CHO* and PHIE from NMR
Cut Off >12% Net Res.
Sand Phie avg.: 23%

SW model from Simandoux adjusted to the electrical parameters of CHO*
Cut Off <60% Net Pay

K calculated with the CHO* parameters, validation was done with K of Timur from NMR
Sand K avg.: 300 mD

*CHO Cerro Hamaca Oeste Analog of Rayoso Fm.

Static Modelling of the Gas Storage Zone

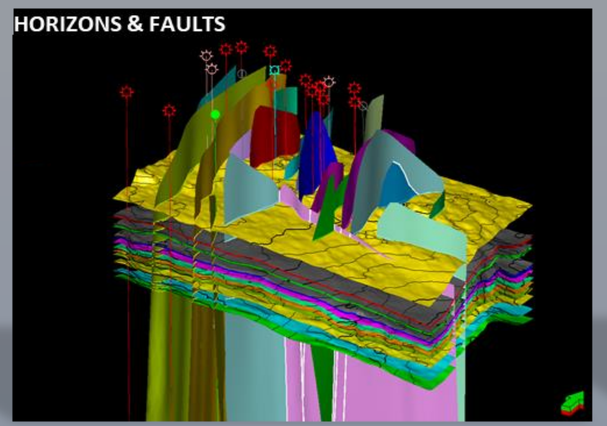


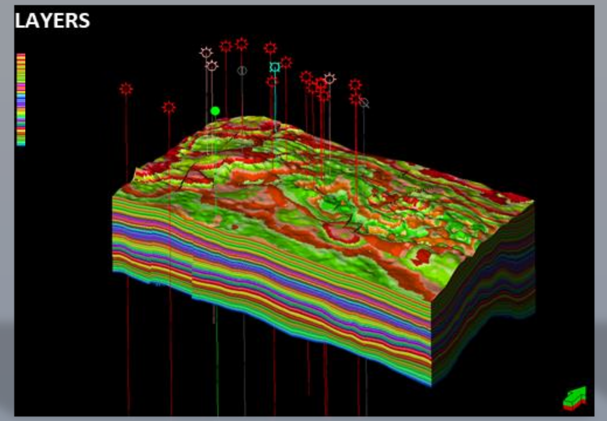
Structural and Grid Model

Rayoso Formation average thickness: 300 m (divided in 13 zones). Area: 98,2 Km^2, small XY cells (50*50 m) and thin layers (125 layers of 3,3 m average thickness) resulted in 6 million-cell model
The Structural Grid was built with 7 main faults and 4 horizons: IntraCenomanian unconformity, Rojo horizon base, Rayoso-6 and Top Centenario.

Basic Workflow

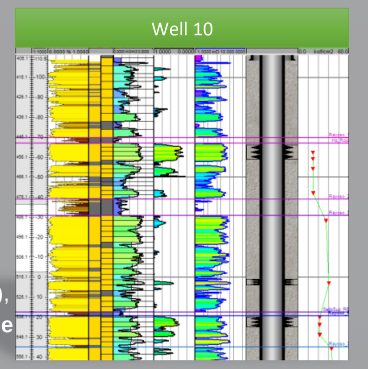
1- Build Structural framework
2- Determine Structural gridding (layers 125)
3- Upscale lithofacies to wells
4- Model lithofacies (SIS)
5- Upscale porosity and SW to wells
6- Model porosity (SGS)
7- Build Fluid Model
8- Calculate OGIP
9- Make Sensibility





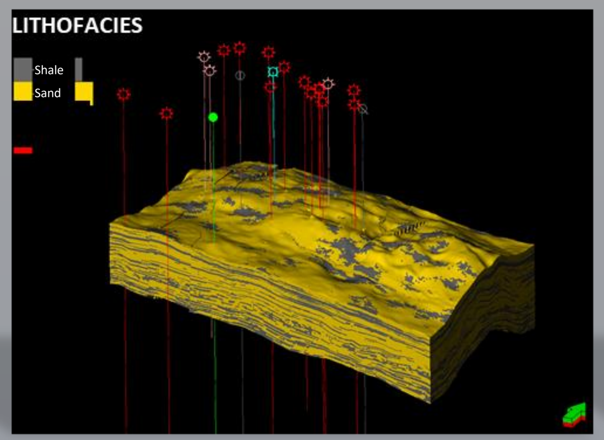
Upscale and modeling lithofacies and properties

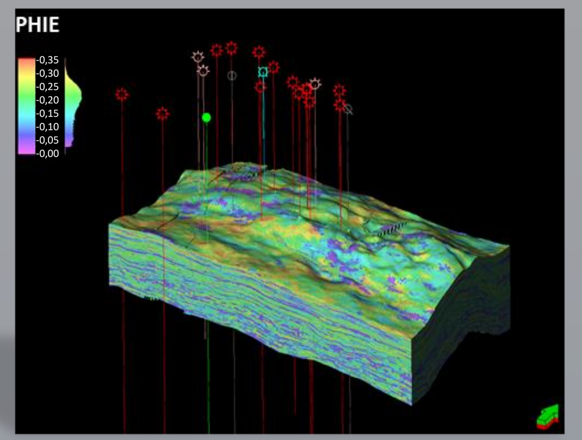
Upscaling: Lithofacies were assigned by "most" criteria and porosity by arithmetical average.
Lithofacies modelling: Sequential indicator simulation (SIS), Connectivity between sands lenses and high proportions of sands.
Porosity modelling: Variogram, Proportion, Sequential gaussian simulation (SGS)

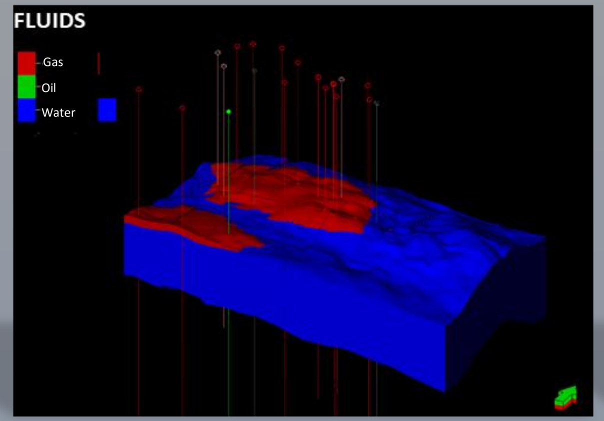


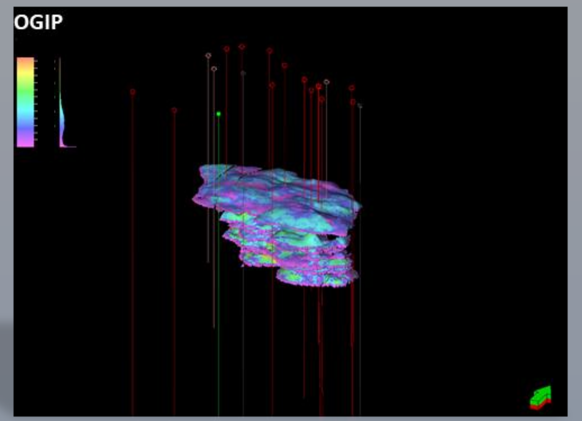
Estimated Original Gas in Place

OGIP was calculated using the following parameters (base case): **NTG** calculated according to the facies distribution (1 for sand and 0 for shale), **PHIE** (cutoff is 12%), the **initial Gas-Water Contact** (GWCi Rojo: 38 m TVDSS), **Gas formation volume factor** (Bg = 0.033), **irreducible water saturation (SWi** = 40%).
A sensibility analysis was performed on the calculation of the OGIP by varying GWCi (38-42 m TVDSS), SW (30-50%), PHIE and NTG seeds. The greatest impact on volume is produced by first two.



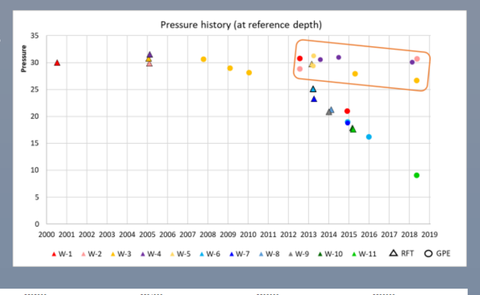


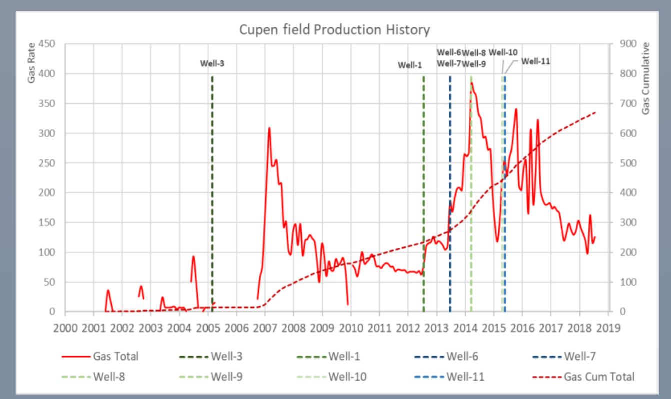


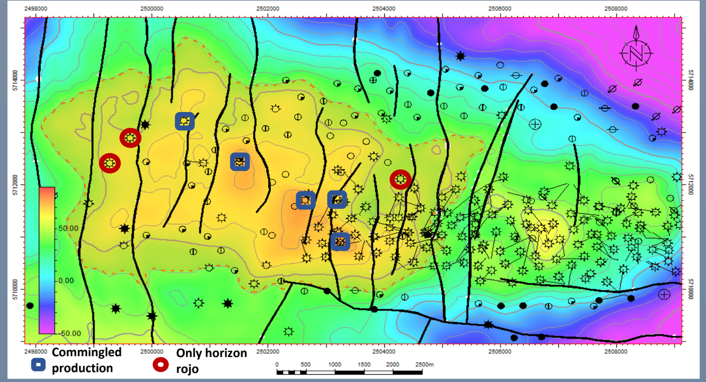


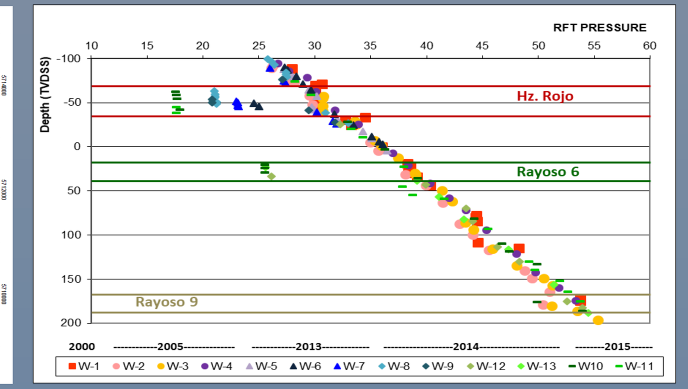
Production and pressure history

There are three producing layers in the Rayoso Formation, the major accumulation comes from the Rojo horizon which also shows the higher depletion as can be seen in the Pressure vs Depth graph.
The current reservoir pressure of the Rojo horizon is about 30% of the original.
The points out of the trend represents wells with commingled production, or wells completed in the Rojo horizon with poor petrophysical properties or not connected to the other wells.



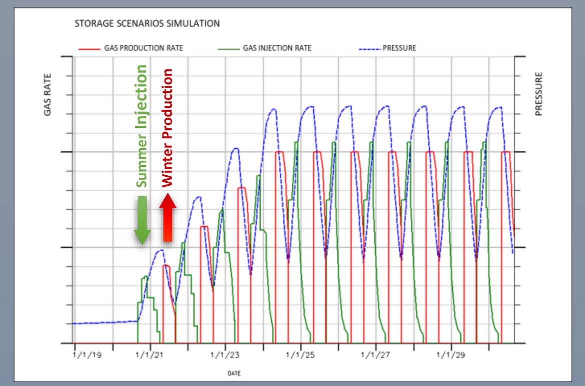


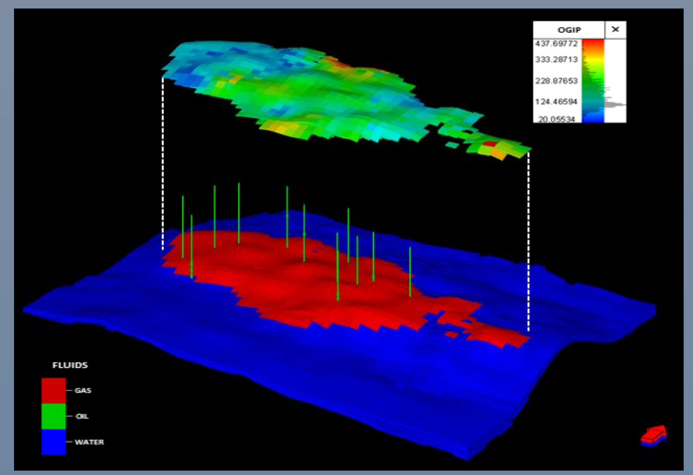




Dynamic model - initial conditions

The static model was used as an input to build the dynamic model, which allowed the evaluation of different scenarios considering different number of wells and injection potential through ten injection – production cycles.





Conclusions

- The physical characteristics of the reservoir became optimal for UGS, as well as the structure and the seal.
- Two different levels had been identified as potential storage due to their wide extension and connectivity.
- The volume calculated with the static model agrees with the volume made through the material balance
- In Addition, the volume needed to inject/produce is appropriate to balance the demand of the field.

Next Steps

- Define an injection pilot test to analyze reservoir properties, admission rate and interferences between areas. At the same time work with the basic engineering (facilities).
- Work in the Project definition including storage design, D&W, and engineering planning overhauls and new facilities.
- Drill core to obtain hard data for petrophysical and geomechanics parameters to adjust the models
- Finally, we plan the main execution of the Project.

Acknowledgements

We would like to thank YPF S.A. for permission to publish this poster. And we acknowledge Aldo Montagna, Marcelo Marteau, Jorge Cavilla, Marcia Faviana, Mercedes Perisse and Juan José Rodriguez for their contribution.

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