Unconventional Resources and the Petrobras Challenges in Argentina*

Tristán Alberto Armaretti[1]

Search and Discovery Article #80436 (2015)**
Posted February 2, 2015

*Adapted from oral presentation given at Geoscience Technology Workshop, Expanding Unconventional Resources in Colombia with New Science - From Heavy Oil to Shale Gas/Shale Oil Opportunities, Bogota, Colombia, December 10-11, 2014

[1]Unconventional Projects Manager, Petrobras, Buenos Aires, Argentina (tristan.armaretti@petrobras.com)

Abstract

After EIA (U.S. Energy Information Administration) publication of June, 2013 ranked Argentina as home to the second largest resource of shale gas and the fourth largest resource of shale oil in the world, it becomes necessary to convert these resources into reserves. Petrobras Argentina operates several exploration and development blocks in the Neuquen Basin with highly attractive prospects in Vaca Muerta formation. Ranked fourth in position among unconventional reservoir operators in terms of operated acreage, the company faces the challenge to apply the technology that has been successfully applied in tight reservoir projects, to shale gas and shale oil projects. Similarly, the technology which was developed by Petrobras in PROCAP, to successfully explore and develop deep-water reservoirs, is now used in the Pré-Sal project. As a shale reservoir, Vaca Muerta formation shows features that distinguish it from similar formations, such as its thickness, equal to three times the average thickness of shale formations developed in the USA.

The importance that Petrobras attaches to Unconventional Resources is reflected by its Investment Plan, in which the CAPEX assigned to unconventional resources accounts for 32% of total investments. Petrobras has undertaken an aggressive development of its tight gas reserves in the Neuquen Basin-centered play, thus acquiring an ongoing learning curve in regard to critical project parameters. Petrobras will use and improve its experience with tight gas to face its shale oil and shale gas challenge. With this goal in view, drilling a shale oil exploration well was started in the Rincón de Aranda block and a shale gas exploration well in the Sierra Chata block, both having promissory results. The key to this challenge is the optimization of aspects such as drilling, completion, and infrastructure. Because of its significance in terms of unconventional reservoirs, the Neuquen Basin will serve as a school of learning for the Petrobras system.

Unconventional Resources

&

The Petrobras Challenges

in Argentina

10/12/2014

Tristán Alberto Armaretti
Petrobras Argentina
Dir. E&P/PRNC

60 AÑOS EN BRASIL 20 EN ARGENTINA

NP-1

Disclaimer

Estas apresentações podem conter previsões acerca de eventos futuros. Tais previsões refletem apenas expectativas dos administradores da Companhia sobre condições futuras da economia, além do setor de atuação, do desempenho e dos resultados financeiros da Companhia, dentre outros. Os termos “antecipa", "acredita", "espera", "prevê", "pretende", "planeja", "projeta", "objetiva", "deverá", bem como outros termos similares, visam a identificar tais previsões, as quais, evidentemente, envolvem riscos e incertezas previstos ou não pela Companhia e, consequentemente, não são garantias de resultados futuros da Companhia. Portanto, os resultados futuros das operações da Companhia podem diferir das atuais expectativas, e o leitor não deve se basear exclusivamente nas informações aqui contidas. A Companhia não se obriga a atualizar as apresentações e previsões à luz de novas informações ou de seus desdobramentos futuros. Os valores informados para 2014 em diante são estimativas ou metas.

A SEC somente permite que as companhias de óleo e gás incluam em seus relatórios arquivados reservas provadas que a Companhia tenha comprovado por produção ou testes de formação conclusivos que sejam viáveis econômica e legalmente nas condições econômicas e operacionais vigentes. Utilizamos alguns termos nesta apresentação, tais como descobertas, que as orientações da SEC nos proíbem de usar em nossos relatórios arquivados.

10/12/2014

Tristán Alberto Armaretti
Petrobras Argentina
Dir. E&P/PRNC

NP-1

Agenda:

1. EIA – 2013 & Unconventional Resources in Argentina
2. Argentina - Energy Aspects
3. Why do we call them Unconventional Hydrocarbons?
4. Unconventional works
5. Petrobras & The Technological Frontier Projects
6. Petrobras In Argentina – PESA
7. Petrobras Challenges in Vaca Muerta
8. Final considerations
9. Questions

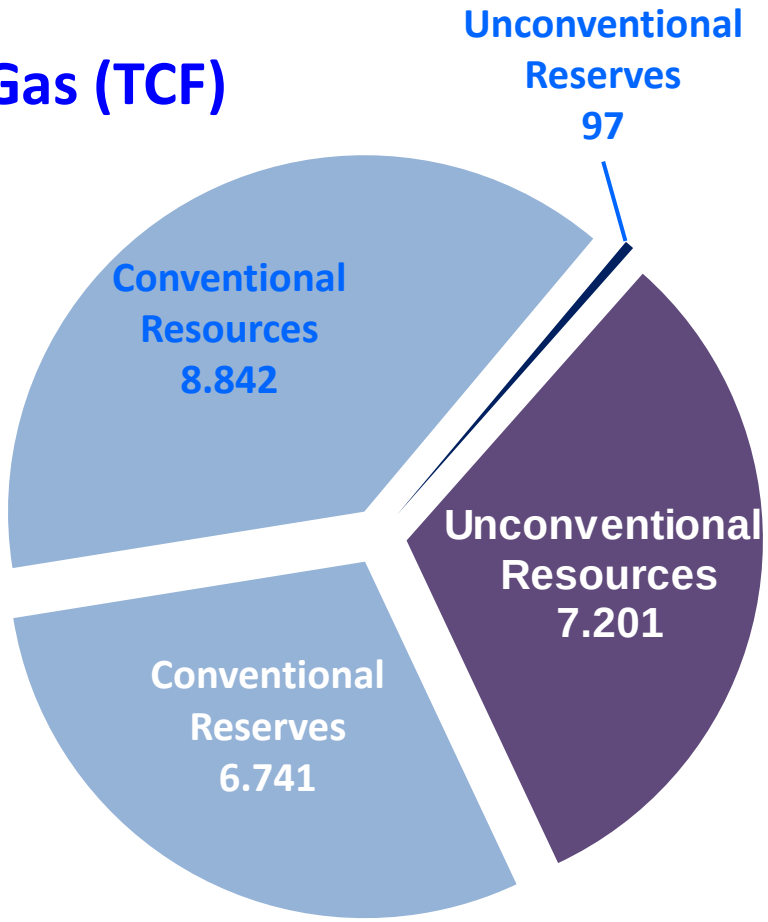
NP-1

Unconventional Resources

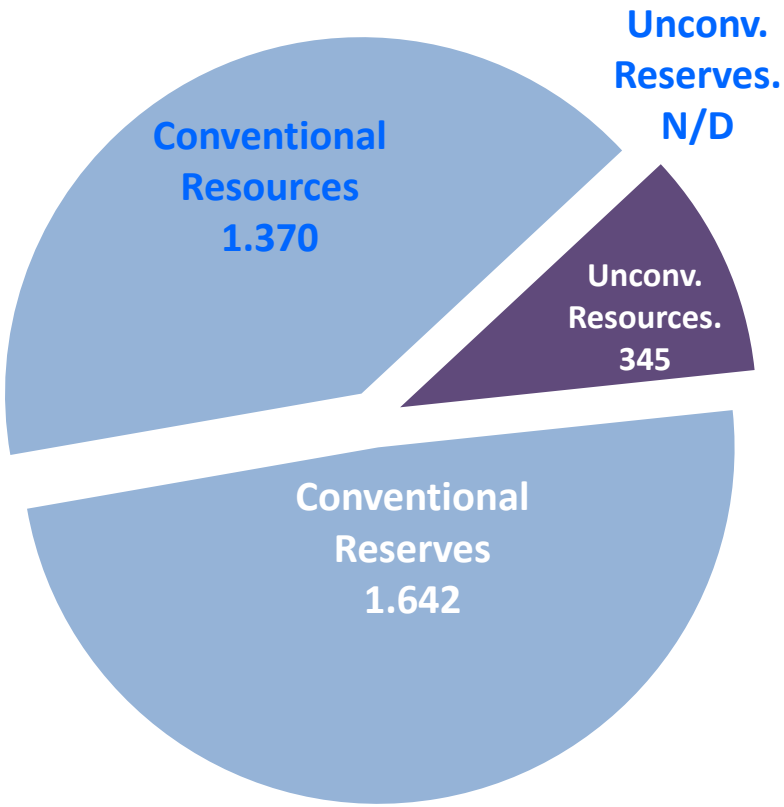
The new horizon for the Oil & Gas industry.....(?)

Gas & Oil in the World

Gas (TCF)



Oil (MMM bbl)



Source: EIA 2013

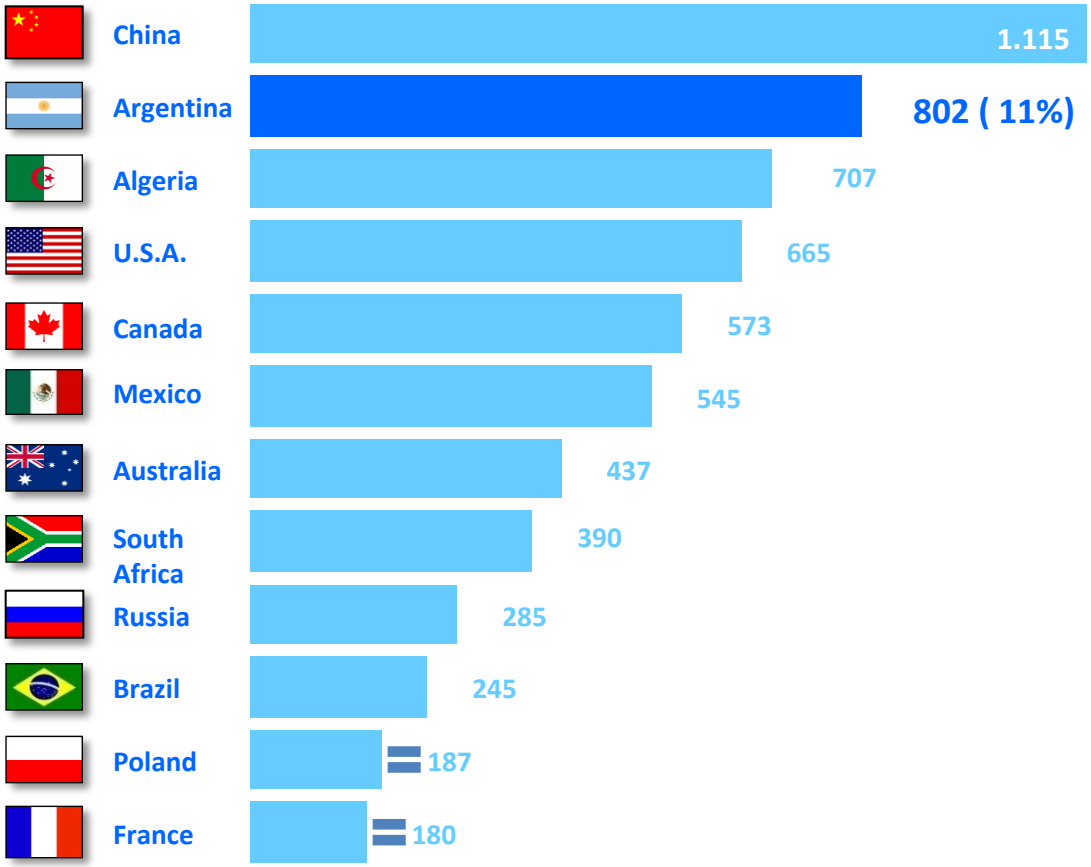
NP-1

EIA – June 2013

Argentinean "shale gas," among the world's largest

Shale Gas Resources technically recoverable

2013 - World Total: 7.299 TCF



"*Shale* Gas" Resources

In production or with activity

- **Neuquén Basin**
  Vaca Muerta
  (shale oil / gas)

  Los Molles
  (shale gas)
- **Golfo San Jorge Basin**

  D-129 (shale oil)

Opportunities

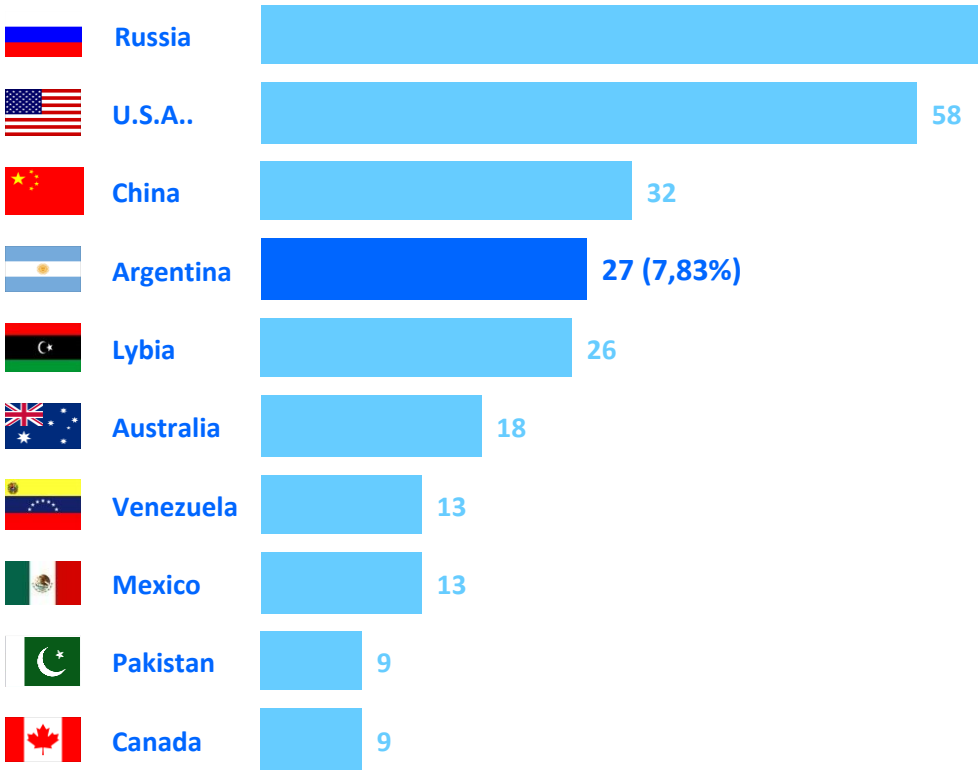
- **Neuquén Basin**
  Agrio (shale oil)
- **Austral Basin**
  Palermo Aike (shale oil/gas)
- **Noroeste Basin**
  Yacoraite
  (shale oil / gas)
  Los Monos
  (shale gas)
- **Chaco Paranaense Basin** (shale oil)
- **Cuyana Basin**
  Cacheuta
  (shale oil)

Source: EIA 2013

EIA – June 2013

Shale Oil Resources technically recoverable

2013 – World Total: 345 billion barrels



In production or with activity

- **Neuquén Basin**
  Vaca Muerta
  (shale oil / gas)

  Los Molles
  (shale gas)
- **Golfo San Jorge Basin**

  D-129 (shale oil)

Opportunities

- **Neuquén Basin**
  Agrio (shale oil)
- **Austral Basin**
  Palermo Aike (shale oil/gas)
- **Noroeste Basin**
  Yacoraite
  (shale oil / gas)
  Los Monos
  (shale gas)
- **Chaco Paranaense Basin** (shale oil)
- **Cuyana Basin**
  Cacheuta
  (shale oil)

Source: EIA 2013

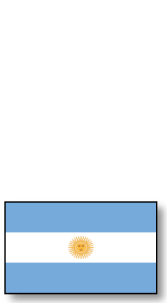
Argentina Unconventional Resources (*shale gas*)

802 TCF

Source: EIA 2013

NP-1

Argentina Unconventional Resources (*shale gas*)



Vaca Muerta

Los Molles

Austral

Chaco-paranaense

3

San Jorge

TCF

Source: EIA 2013

NP-1

Argentina Unconventional Resources (*shale gas*)

308 TCF

Vaca Muerta

Source: EIA 2013

NP-1

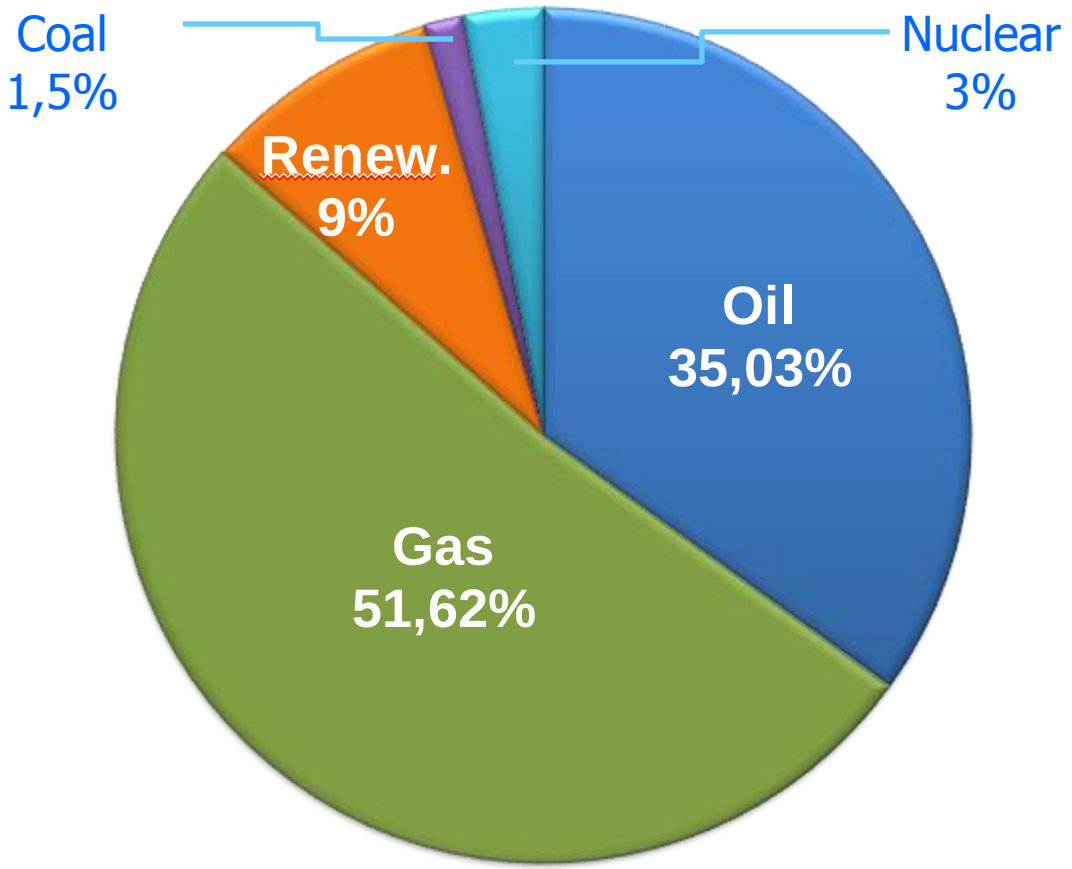
Argentina Unconventional Resources (*shale gas*)

Source: EIA 2013

NP-1

Energetic Consumption

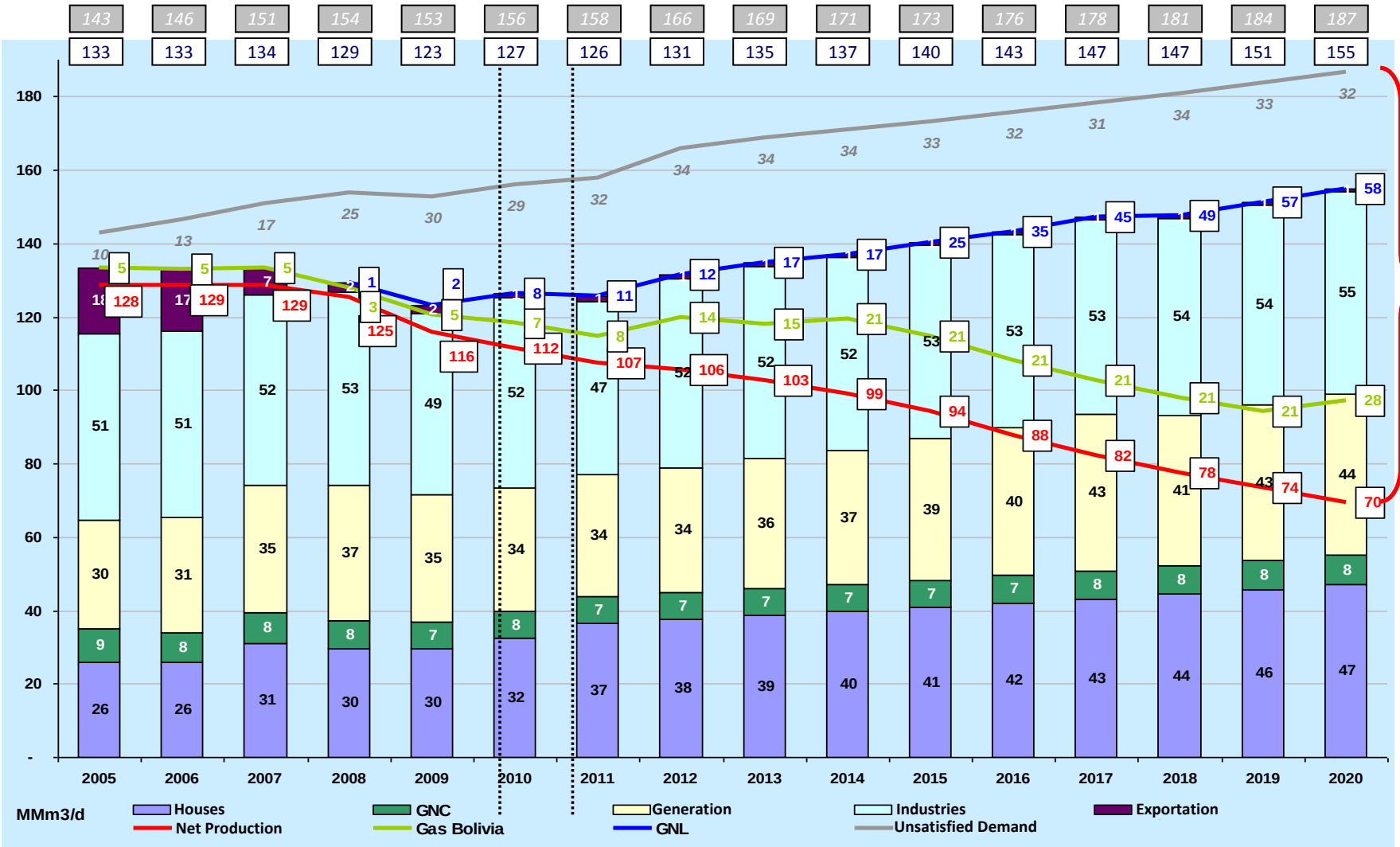
86% of the energy matrix depends on hydrocarbons



Source: Secretaría de Energía de la Nación

NP-1

Gas: Production & Consumption



GAS GAP 117 or 85 MM m^3/d

Source: PESA

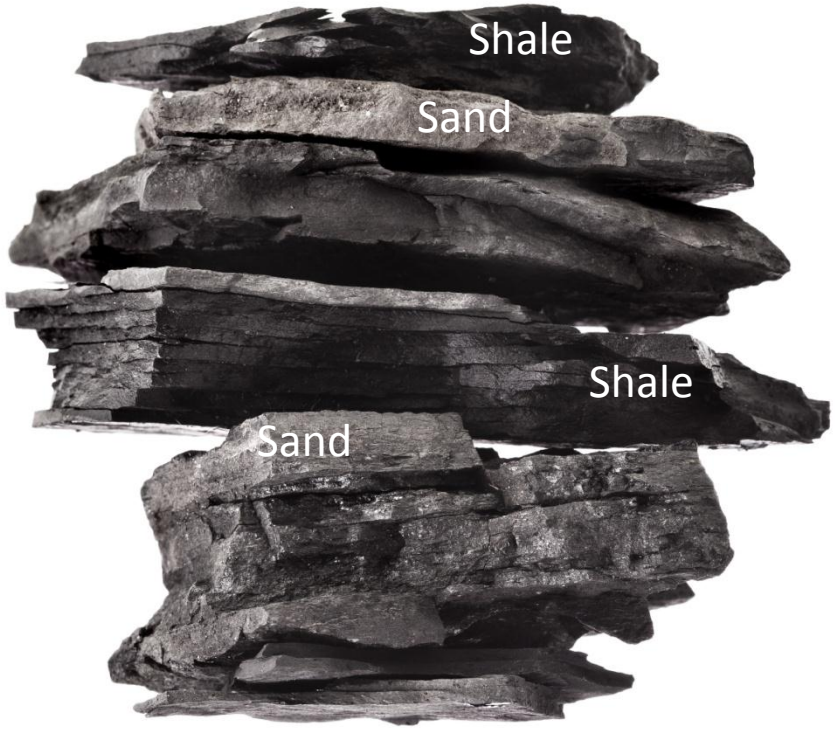
¿Why do we call them Unconventional Hydrocarbons?

✓They are exactly the same as Conventional ones.

✓The difference arises from the type of reservoir in which they are found.

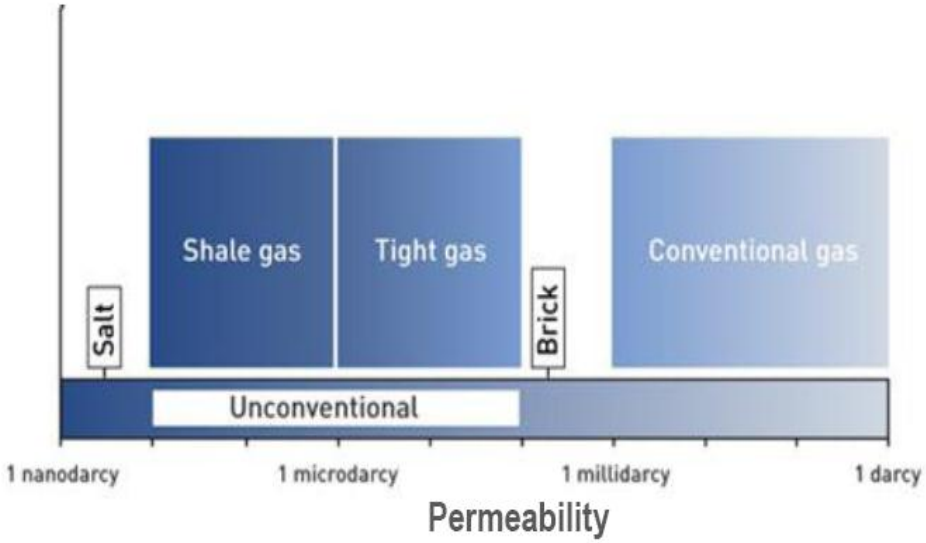
✓In the case of the so-called shale, it is located in formations of schist and shale rocks of low or very low permeabilities

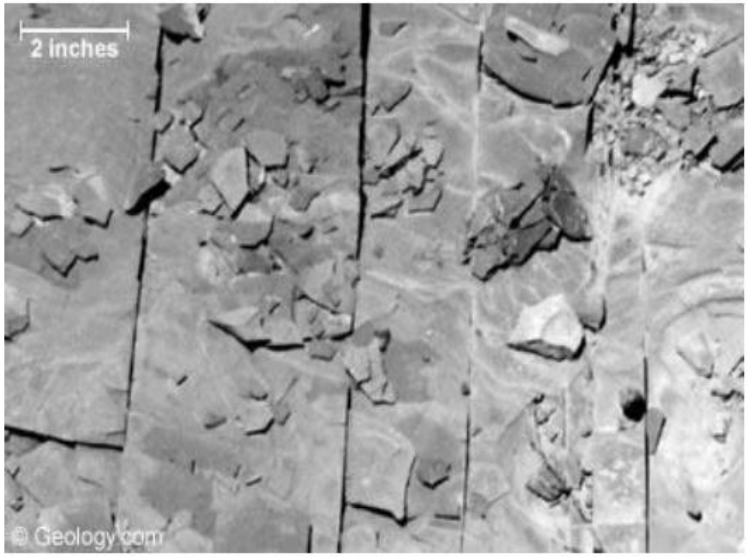
✓To extract them it is necessary to generate secondary permeability, through hydraulic stimulation.



NP-1

Porosity and permeability in shales

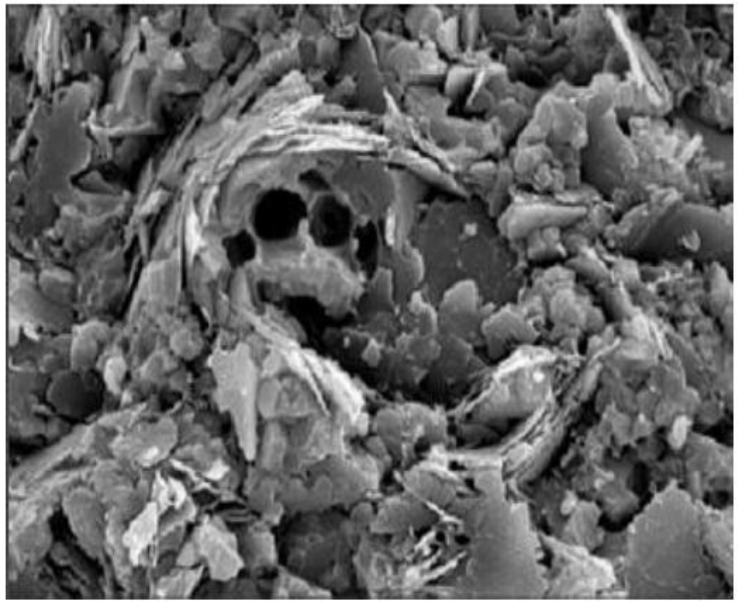




jahschem.wikispaces.com/Marcellus+Shale

- Permeabilities in the range of "nano", very complex porous system
- Natural fractures play an important role
- Hydraulic fracturing is mandatory!

Organic content, maturity and mineralogy

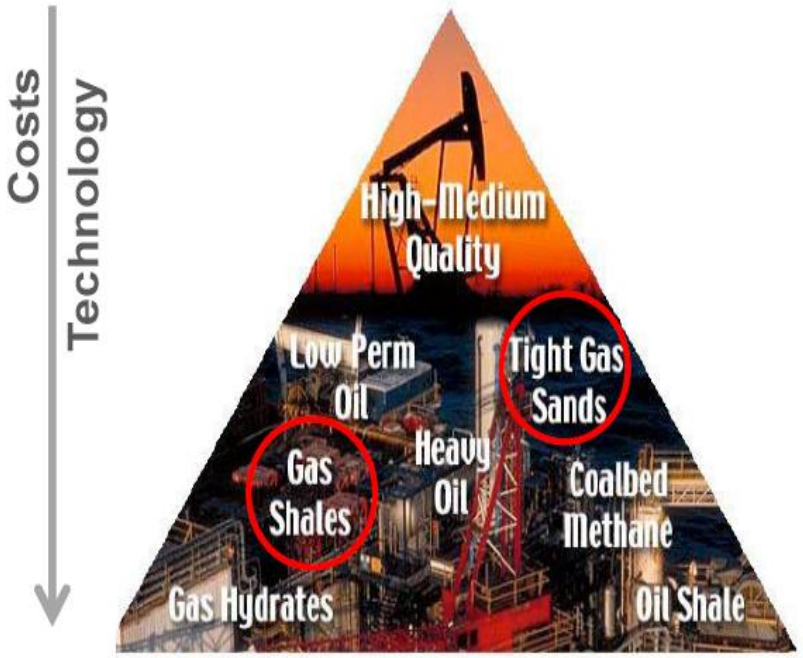


Shale under SEM, ypf.com/energiaypf/paginas/vaca-muerta.html

VM outcrop. Geoexpro.com/articles/2012/02/argentina-unconventional-discoveries

- Recovery and productivity potential depend on organic content
- Maturity (time, temperature, depth) defines fluid boundaries
- Mineralogy qualifies for *fracking*

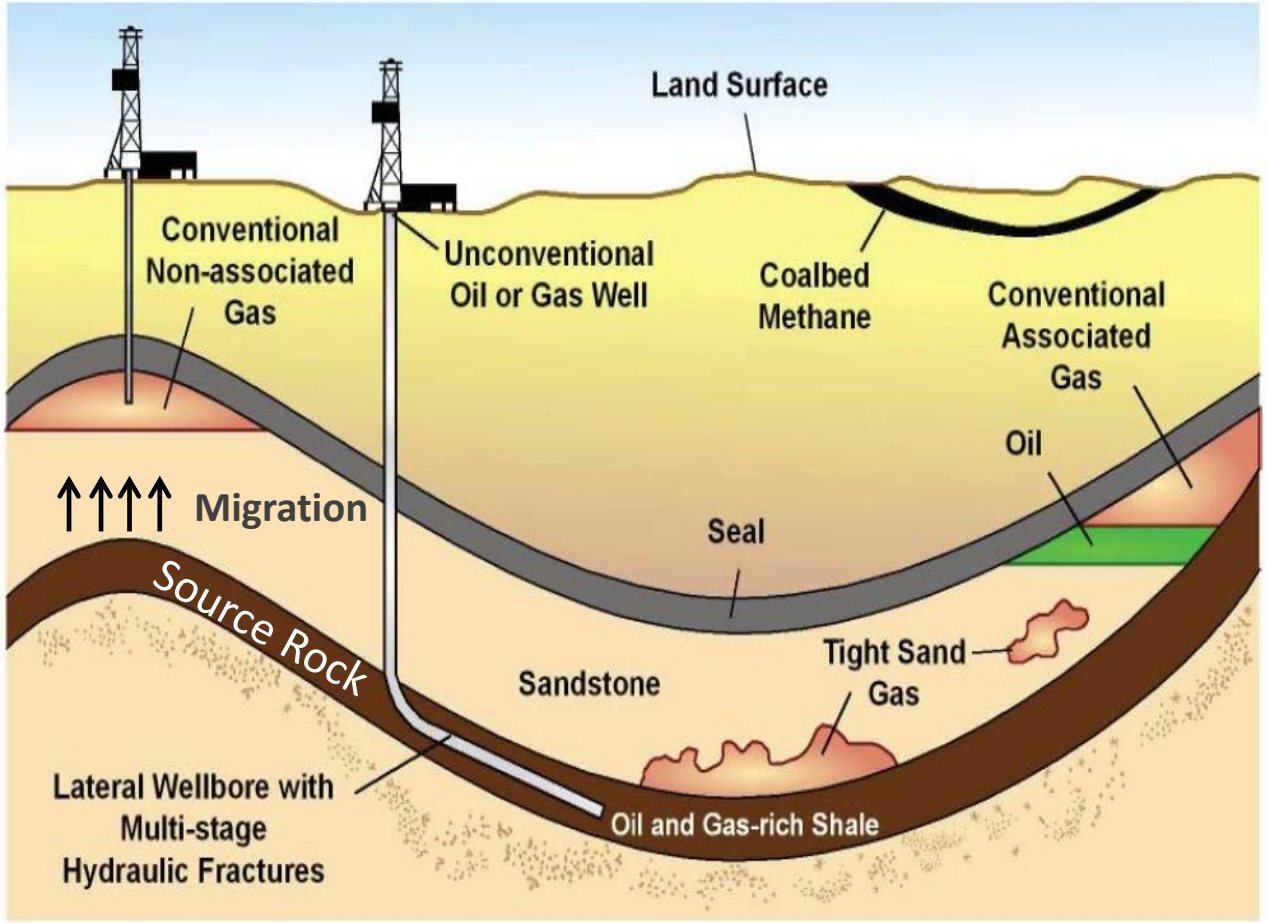
And what are "Unconventional systems"?



- Both surface and subsurface
- No traps, undefined boundaries
- Source may be "reservoir" rock
- No fluid segregation
- Undefined fluid contacts
- No volumetric "analogy"
- Recovery factor related to projects
- Risk is a *different* risk

Conventional vs. Unconventional Exploitation

The Geology of Conventional and Unconventional Oil and Gas



Source: EIA

✓Unconventional resources have been known for decades, but couldn't be exploited until recently.

✓They can be extracted by means of vertical or horizontal wells.

✓They require larger investments than conventional hydrocarbons.

NP-1

U. S. A. a successful case

"We must start developing new unconventional energy sources now, as they will lay the foundations for the next century"
President Jimmy Carter, 18/4/1977

On **9/11/1978 Natural Gas Policies Act** became effective, which allows for special prices to foster unconventional gas resources development.

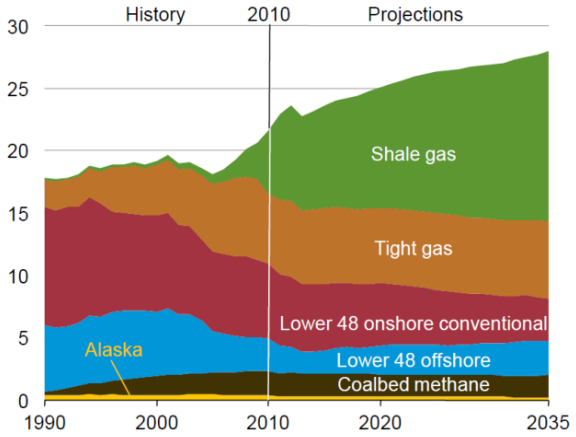
NP-1

U. S. A. a successful case

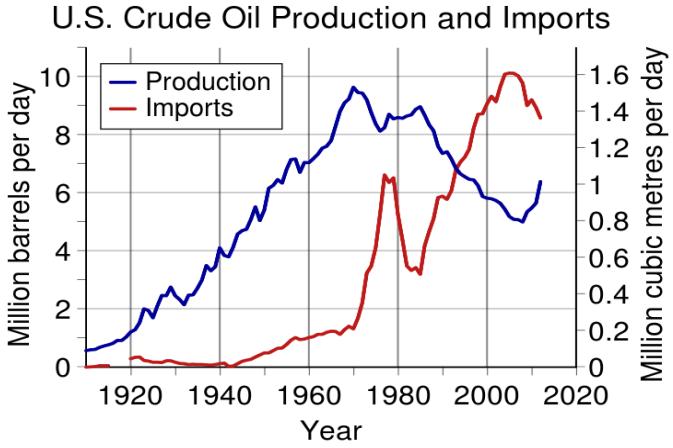
U.S. gas production increase is mainly due to the development of unconventional resources.

Thanks to it, it was possible to revert the declining trend of conventional gas production and even to approve a few gas export projects.

Gas Production (Tcf)



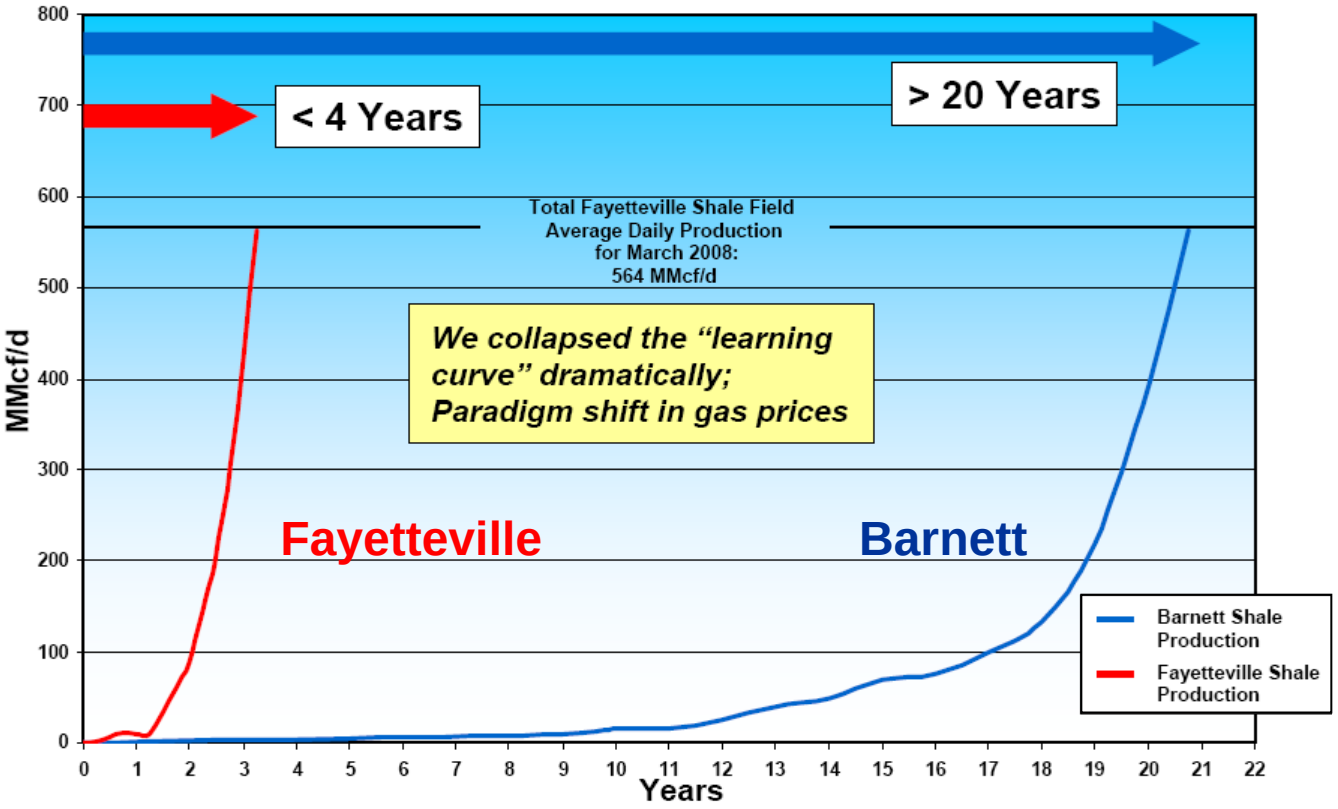
Oil Production(M Bbl/day)



NP-1

- **In North America, the processes of research and development of technologies to produce and to optimize the development of these deposits required between 15 and 20 years.**

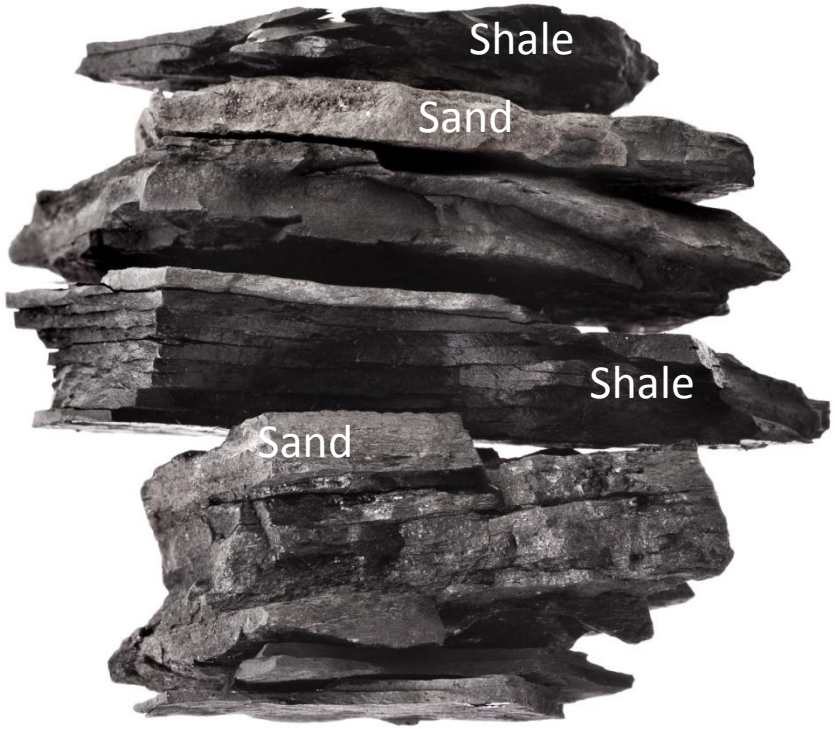
- **The successful application of known technologies made it possible to shorten the learning process in later developments.**



Source: Tudor, Pickering,Holt & Co. Securities, Inc., Arkansas Oil & Gas Comission.

NP-1

Unconventional Works



Unconventional reservoir

NP-1

Hydraulic Stimulation

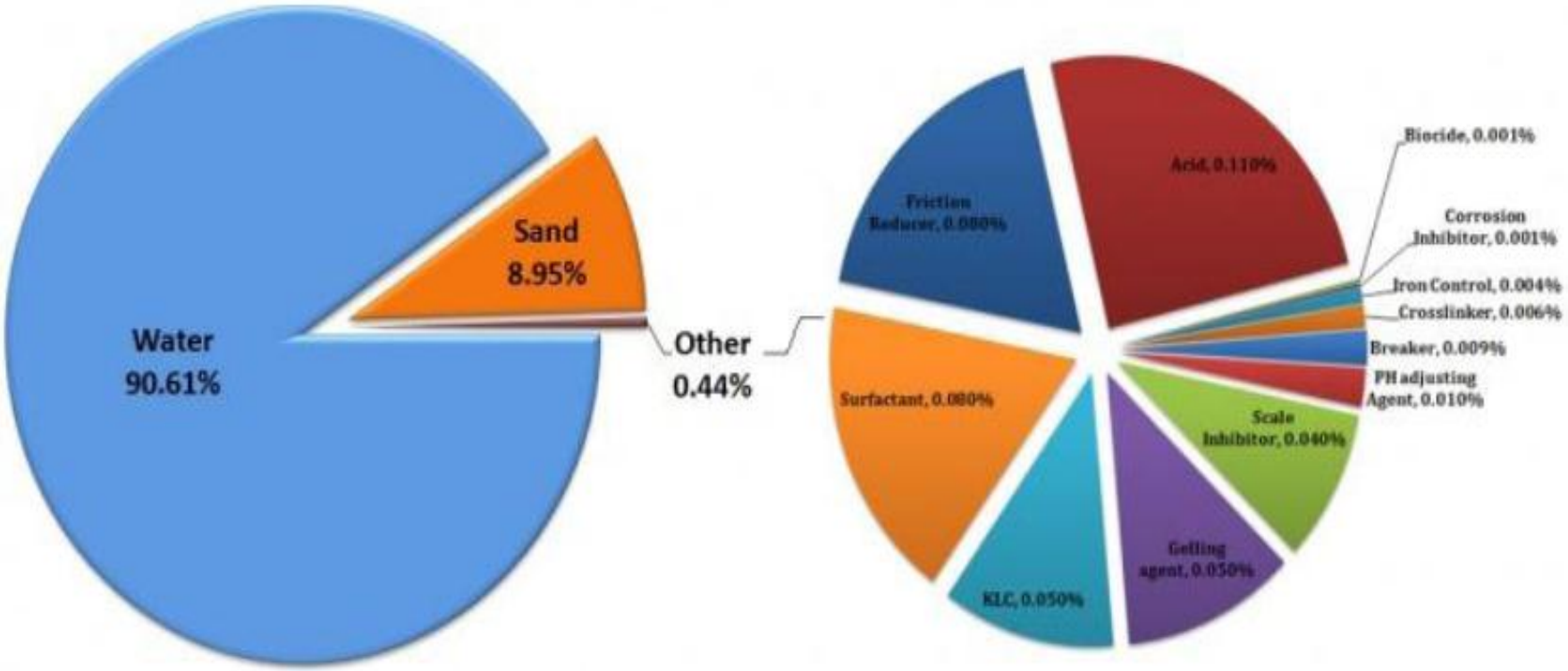
- It generates secondary permeability, which enables the hydrocarbon located within the reservoir to flow to the well.

- It contains:

WATER :	~ 90.61%
SAND:	~ 8.65%
ADDITIVES:	~ 0.44%

Source: Provincia de Neuquén & PESA Foto

Hydraulic Stimulation



NP-1

Hydraulic Stimulation

Chemical Additives

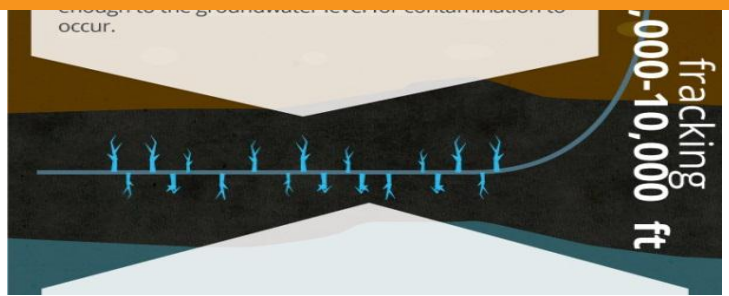
Chemical additives only represent ~ 0.45/0.50 % of the fluid.

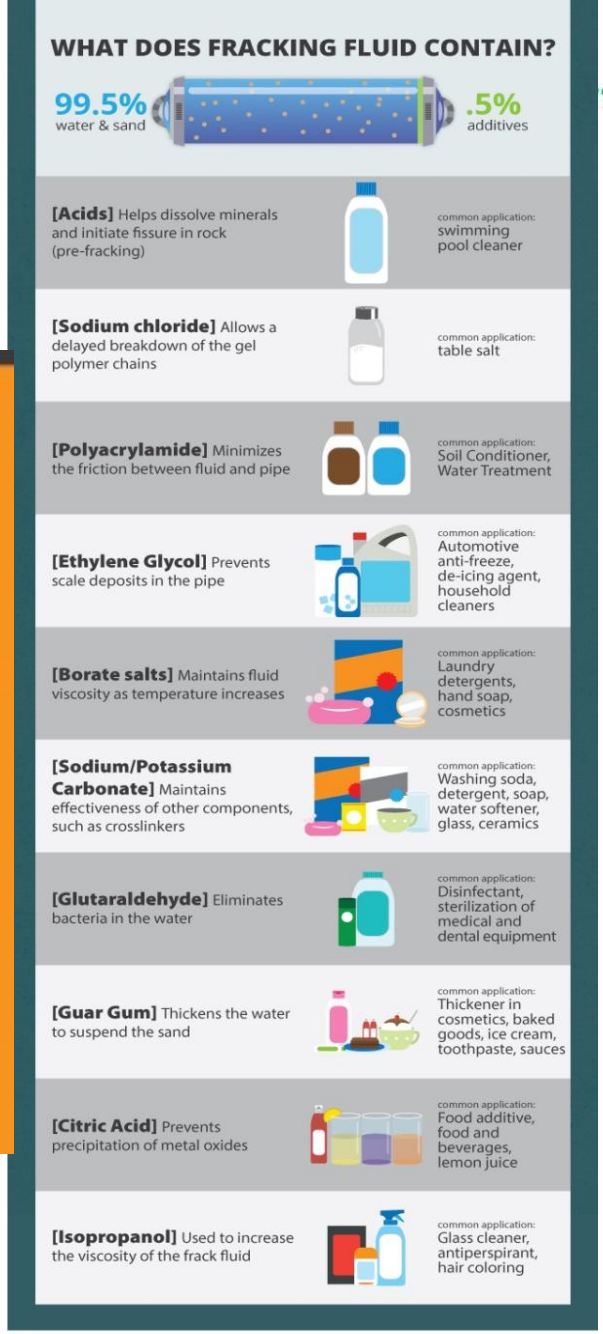
They are used in everyday life.

Oil & gas industry uses them at lower concentrations than at home.

ADDITIVE	FUNCTION IN THE FLUID	HOUSEHOLD USE
Acids	They help dissolve rock matrix minerals	Swimming pool cleaner
Glutaraldehyde	Removes water bacteria	Disinfectant used by dentists
Sodium chloride	It delays polymer chain degradation	Food salt
N- Dimethyl	It prevents casing corrosion	Pharmaceutical and plastic products
Borate salts	They keep fluid viscosity	Personal use soap and cosmetics
Distillates	They reduce water friction	Make-up removers, laxatives, candies
Guar gum	It thickens water and prevents sand precipitation	Cosmetics, ice cream, toothpaste, dressings
Citric acid	It prevents metal oxide precipitation	Additive for foods, juices, etc.
Potassium chloride	Brine improving fluid circulation	Low-sodium food salt
Potassium carbonate	It keeps other substances effectiveness	Soap, glass, ceramic
Glycol	It prevents casing scaling	Household cleaning agents, putty
Isopropanol	Used to increase injection fluid viscosity	Glass cleaners, deodorants, hair dyers

* Adicionalmente, en algunos casos se utilizan solventes en cantidades muy bajas, como el gasoil o los aceites vegetales





TROBRAS

For more on investing in the American Energy Revolution, visit us at **crude.com/invest**.

CRUDE ENERGY

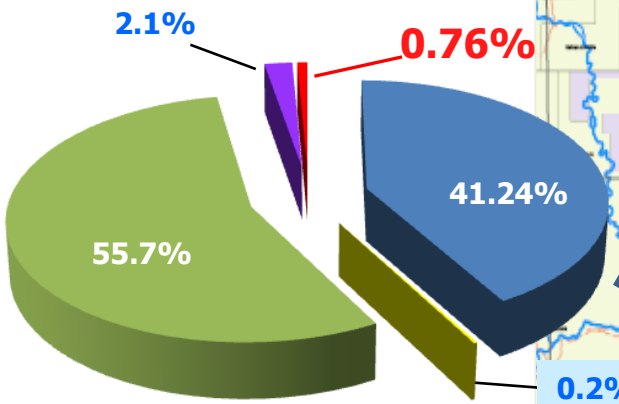
NP-1

Use of water resources in The Neuquén Basin

PETROBRAS

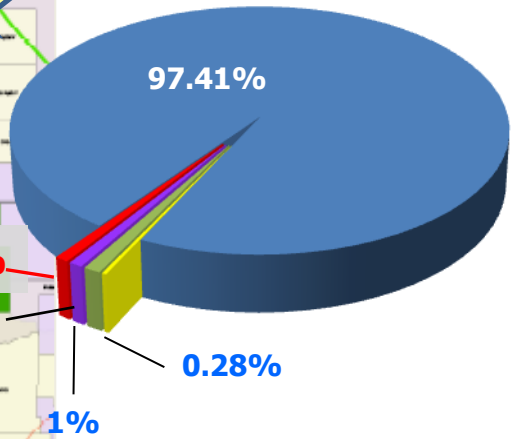
+ Unconventional uses

Neuquén River



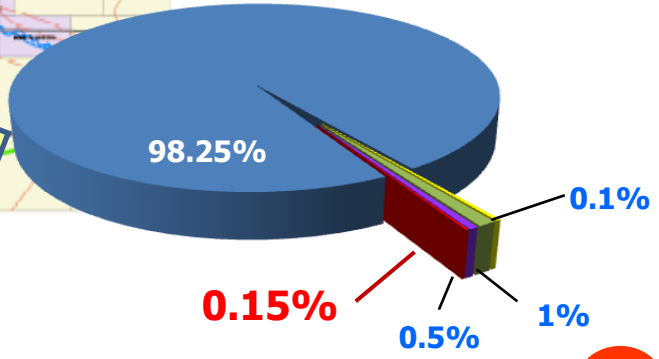
3,153,600,000 m3/year

Colorado River



1,261,440,000 m3/year

Limay River



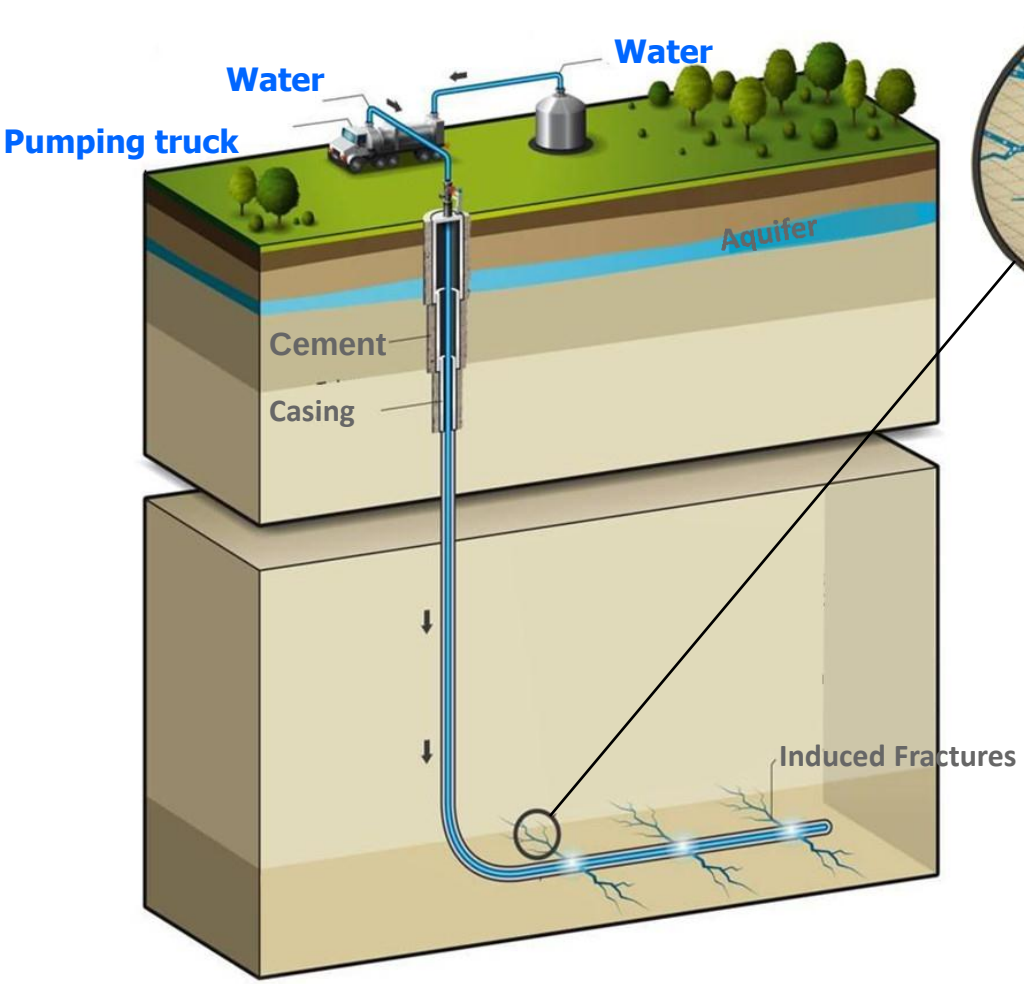
6,622,560,000 m³/year

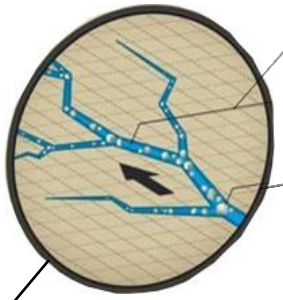
- Population
- Irrigation
- Industry
- Unconv.Resources
- Remaining Resources

* According to Five-year Plan (2500 wells in 5 years)

NP-1

Aquifer Isolation





Water +sand +additives

Sand keeps induced fractures open

Major safety steps are adopted to isolate formations and aquifers

Steel casings with adequate schedule in aquifer area and casing cementing at all phases

* Not in scale

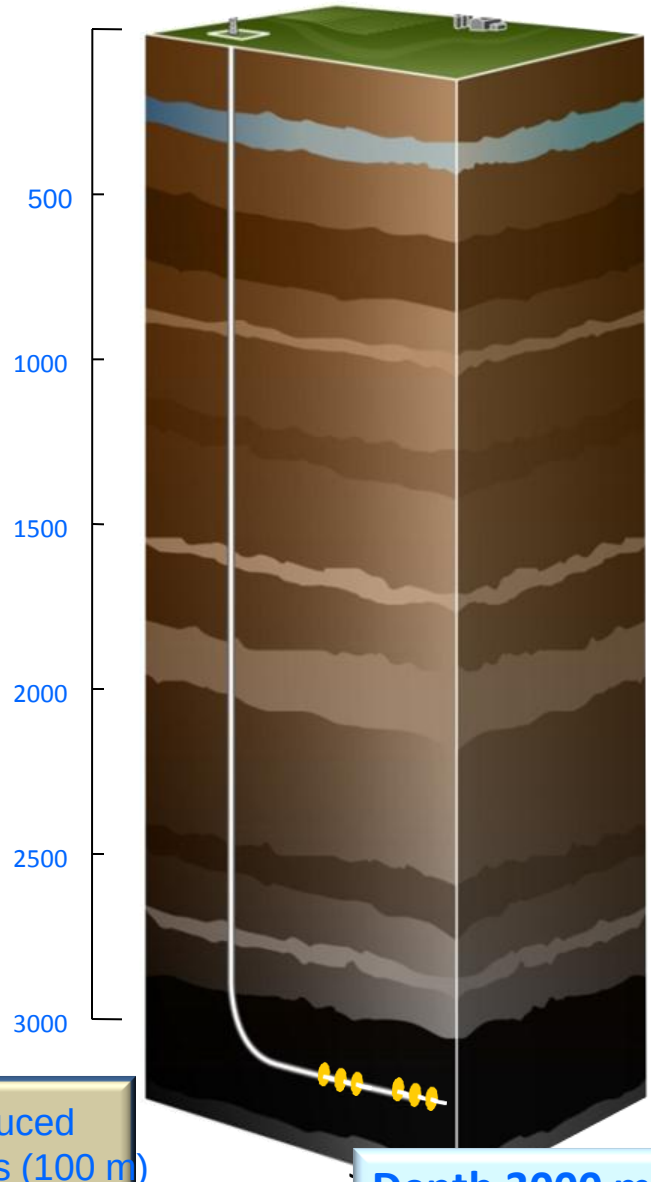
Depth

Operations take place thousands of meters below ground level, away from any fresh water aquifer

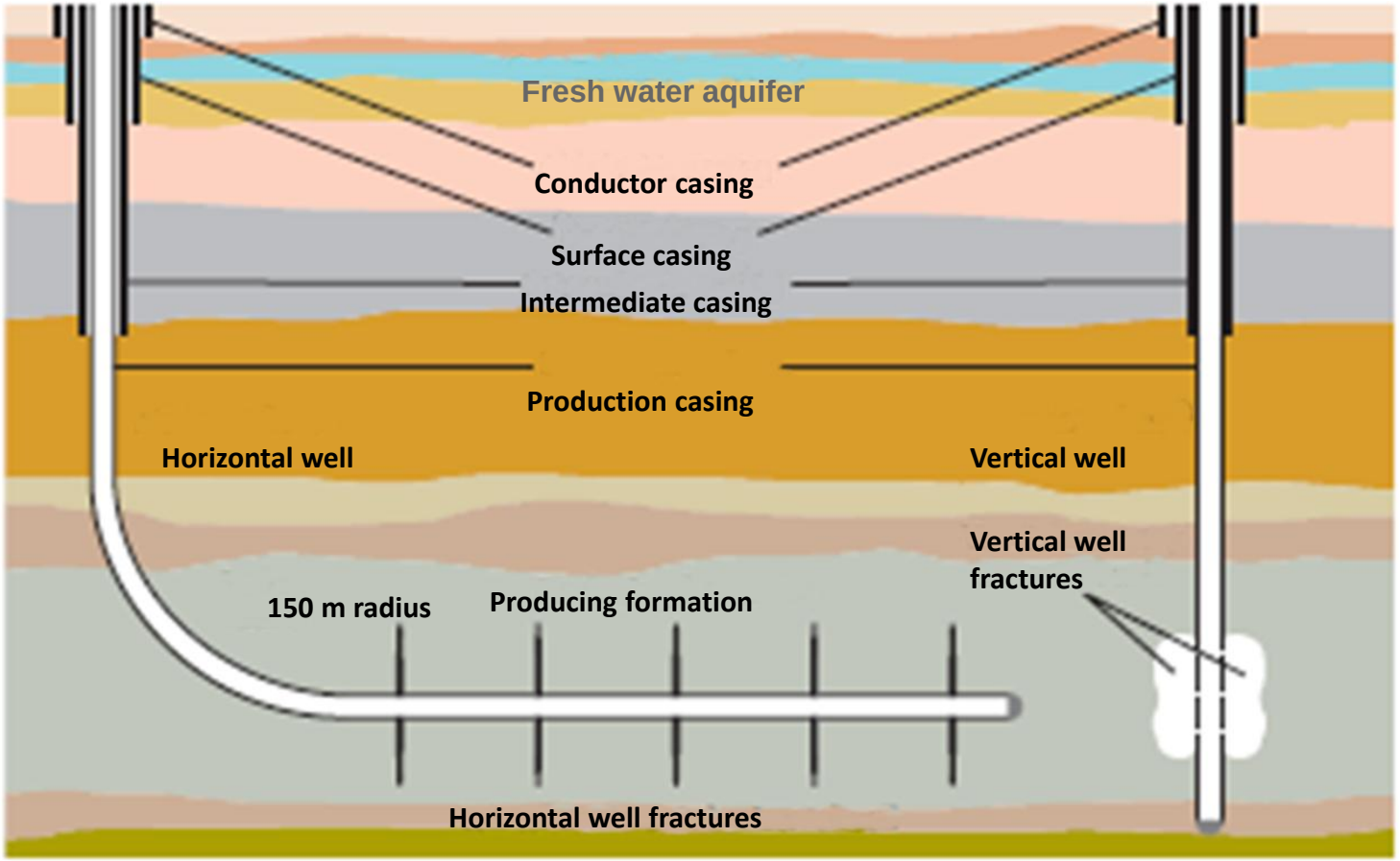
Induced fracture radius traditionally does not exceed100 m

Maximum induced fracture diameter is 2 to 3 mm

Most induced fractures run parallel to the surface

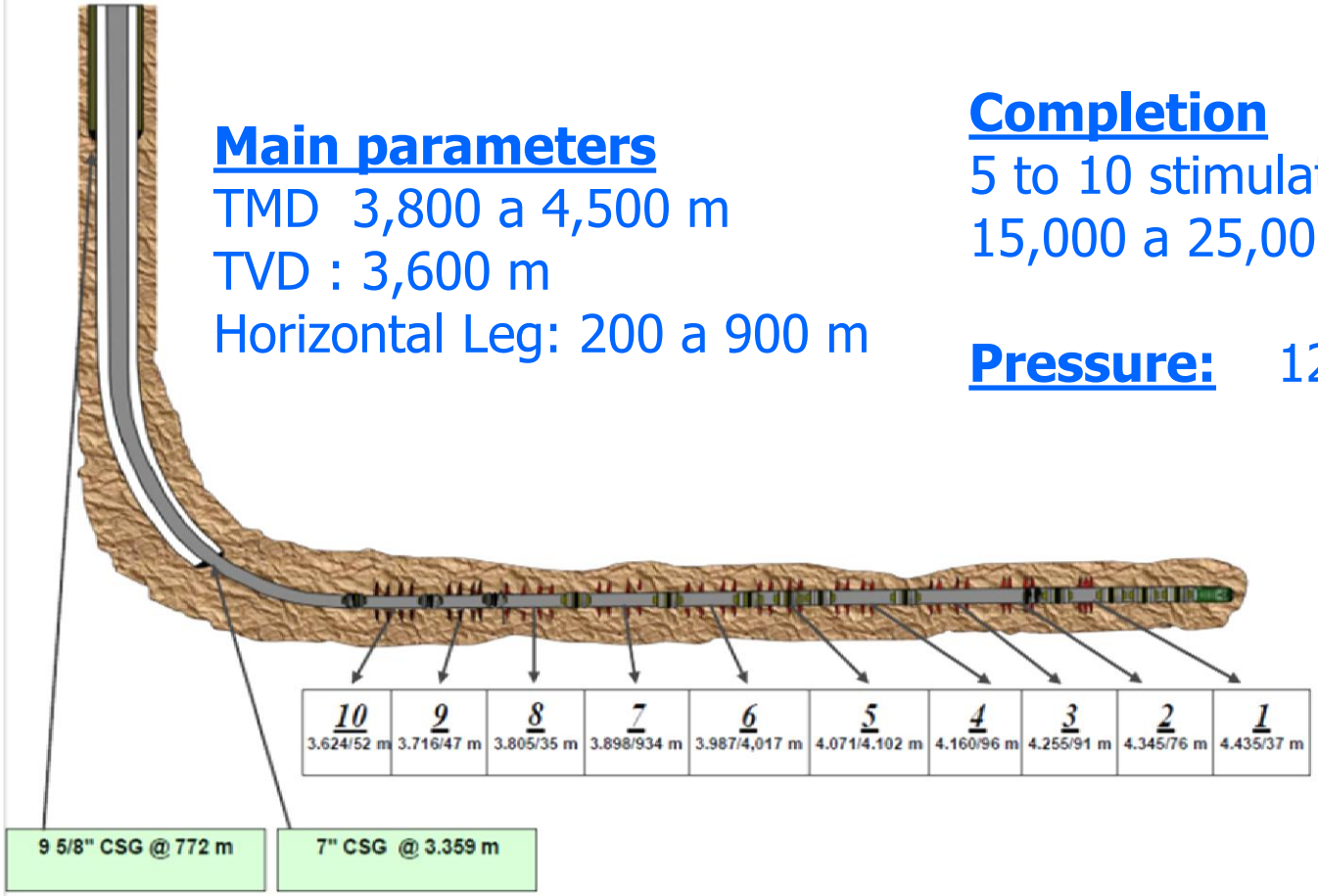


Unconventional Well Layout



NP-1

Multifracs in Horizontal Well



Main parameters

TMD 3,800 a 4,500 m

TVD : 3,600 m

Horizontal Leg: 200 a 900 m

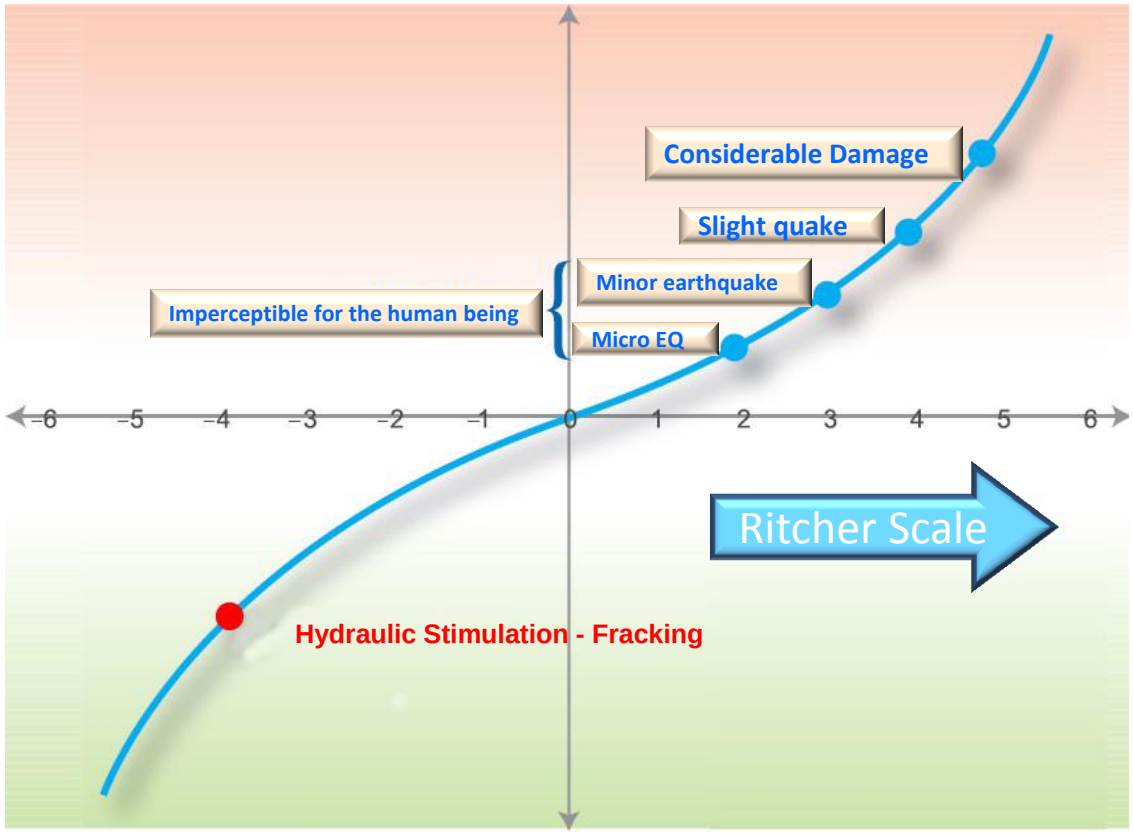
Completion

5 to 10 stimulation stages

15,000 a 25,000 m3 of water

Pressure: 12,000 psi

Seismics



✓Hydraulic stimulation generates seismic activity, but not earthquakes (earthquakes capable of causing damage).

✓The magnitude of the above mentioned activity is thousands of times lower than perceptible ones for human beings.

✓Until 2012 more than 250,000 stimulation operations were performed and no significant earthquakes related to this activity were reported.

33

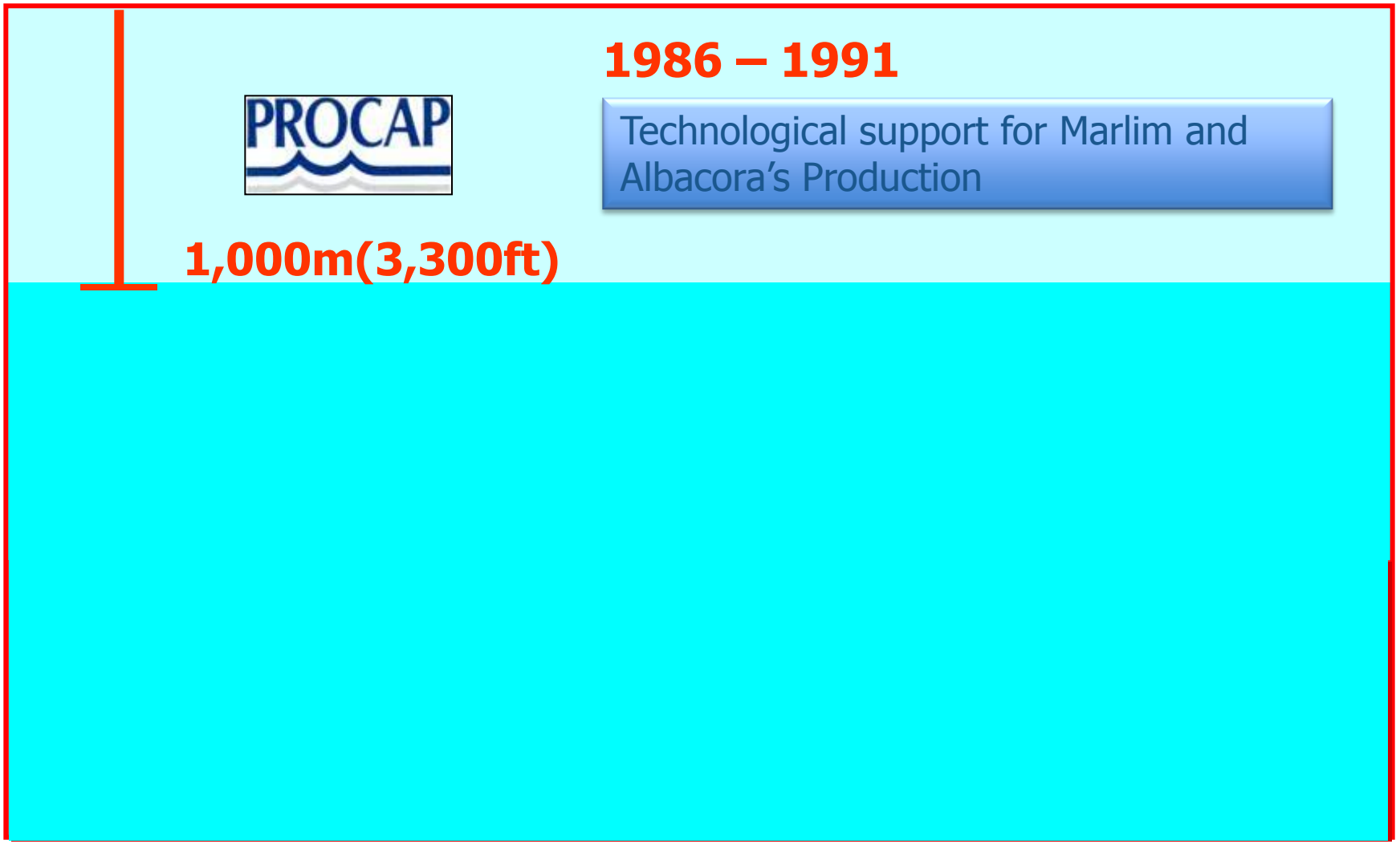
NP-1

Petrobras

&

The Technological Frontier Projects

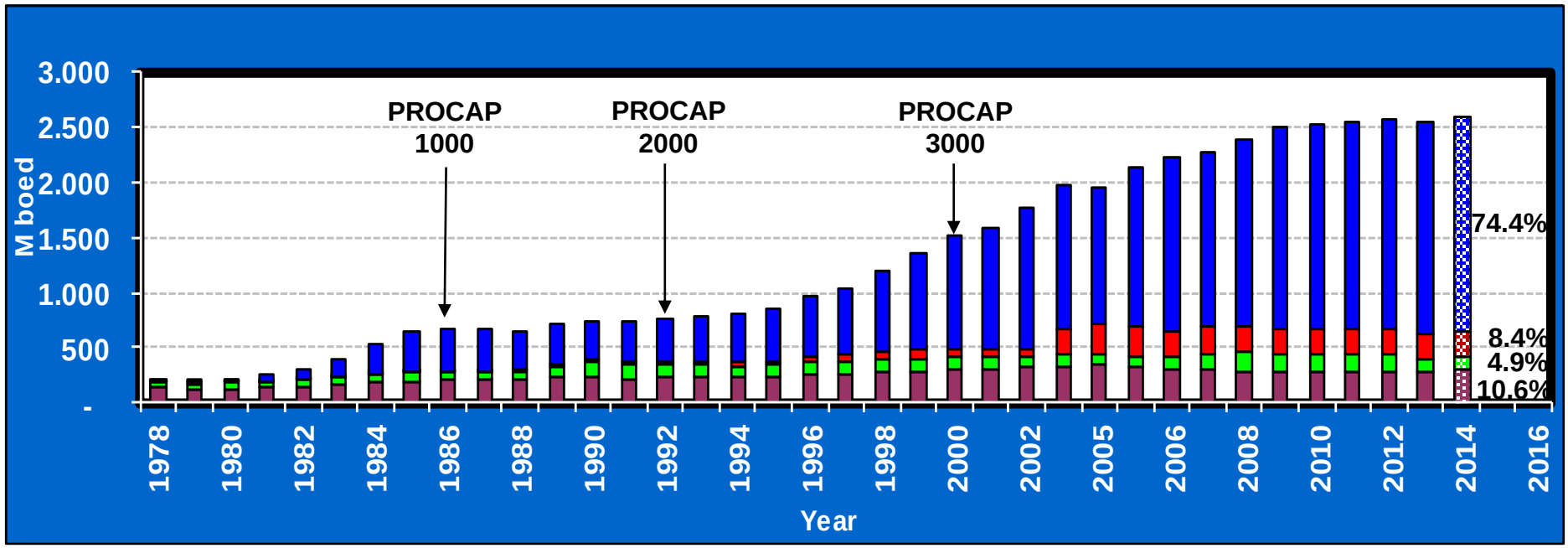
Deep Water Training Program – PROCAP by Petrobras



NP-1

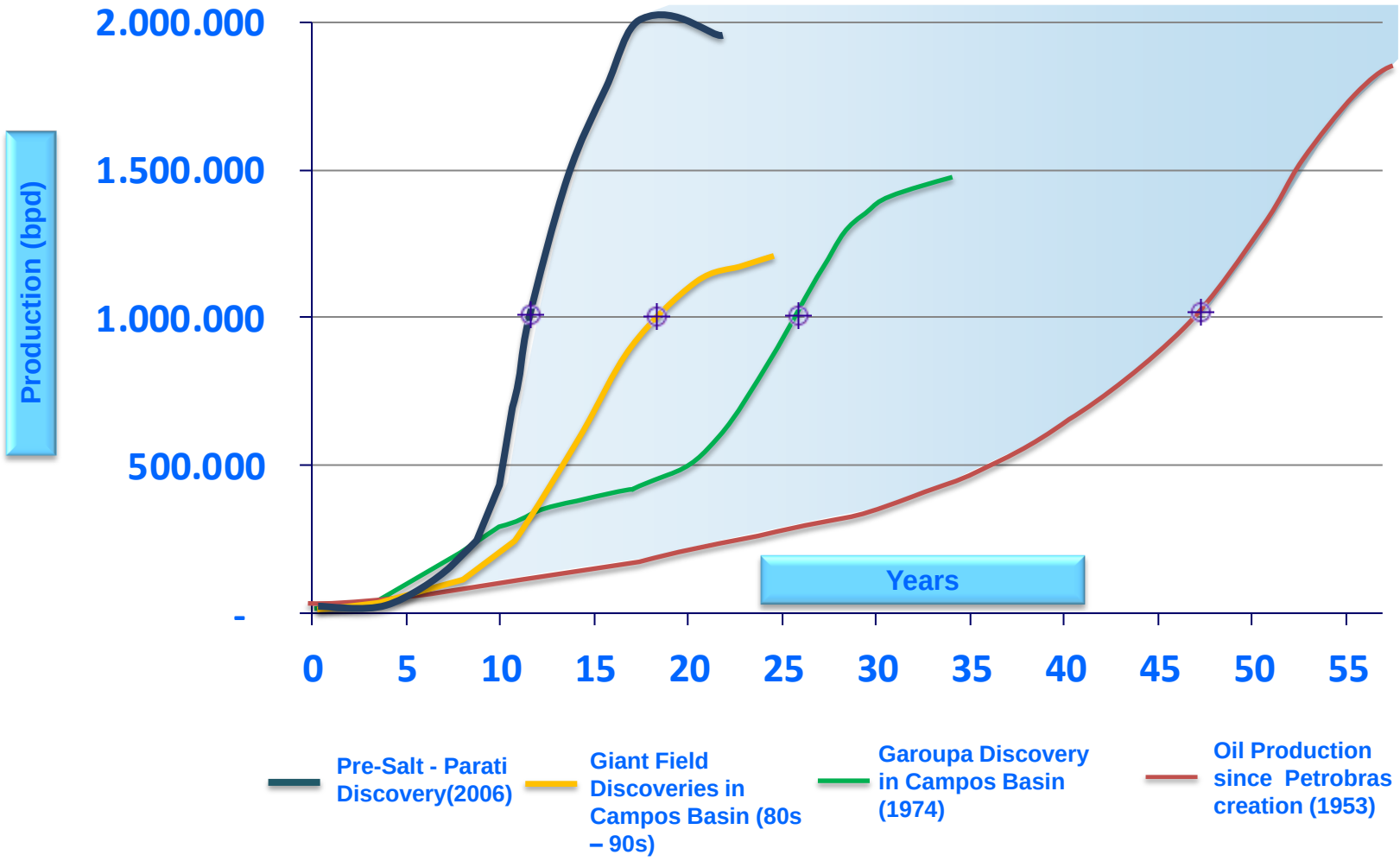

P1000
P2000
P3000

Oil equivalent production



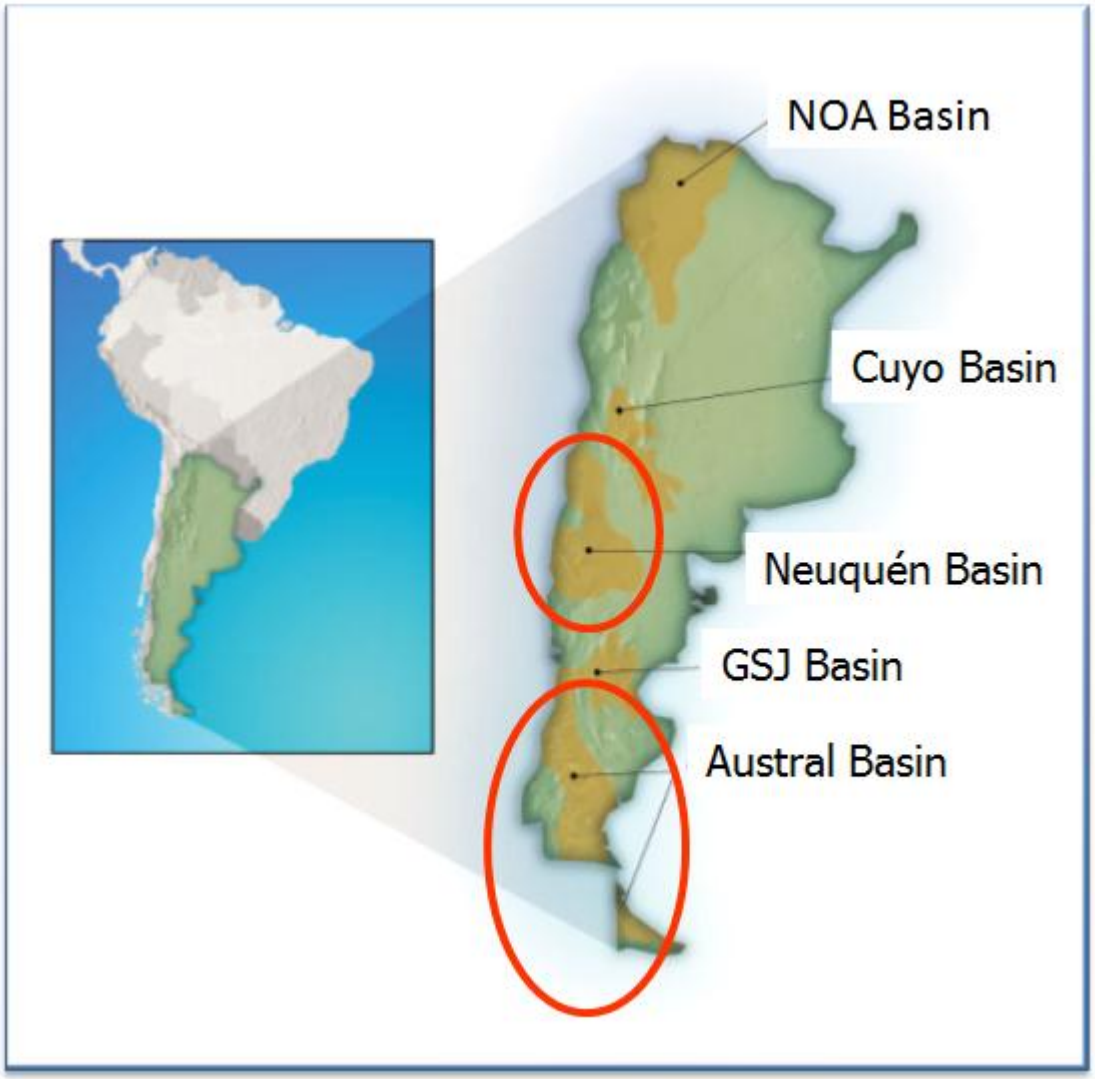
Land Sea <= 300m ANI Sea > 300m 2014 Proj.

NP-1


Production (bpd)
2.000.000
1.500.000
1.000.000
500.000
-
0
5
10
15
20
25
30
35
40
45
50
55
Years
Pre-Salt - Parati Discovery(2006)
Giant Field Discoveries in Campos Basin (80s – 90s)
Garoupa Discovery in Campos Basin (1974)
Oil Production since Petrobras creation (1953)

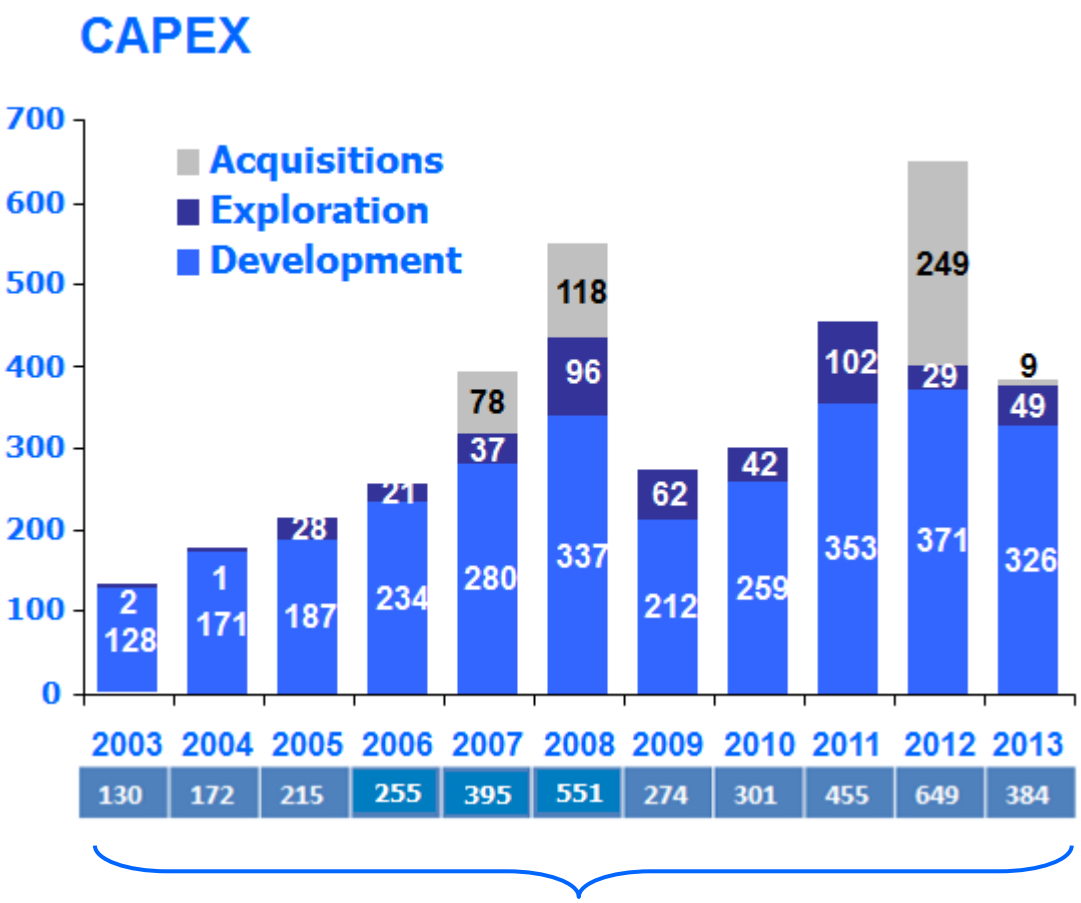
NP-1

Petrobras in Argentina - PESA

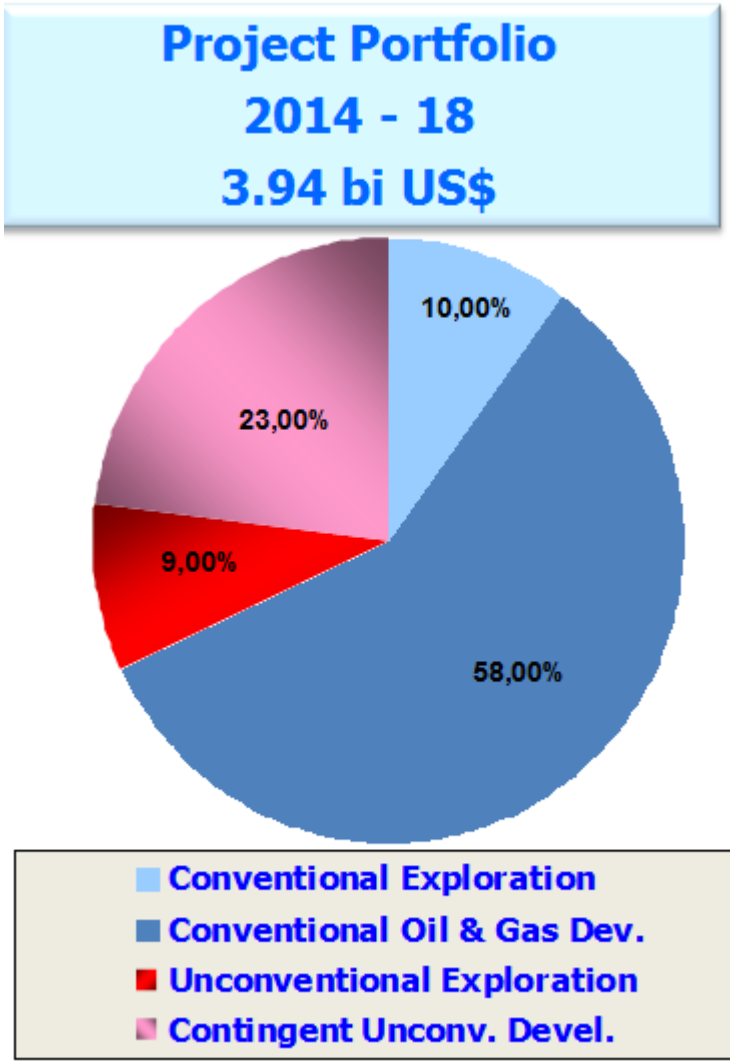


NP-1

Petrobras Argentina Investments (PESA)



3.78 bi US$

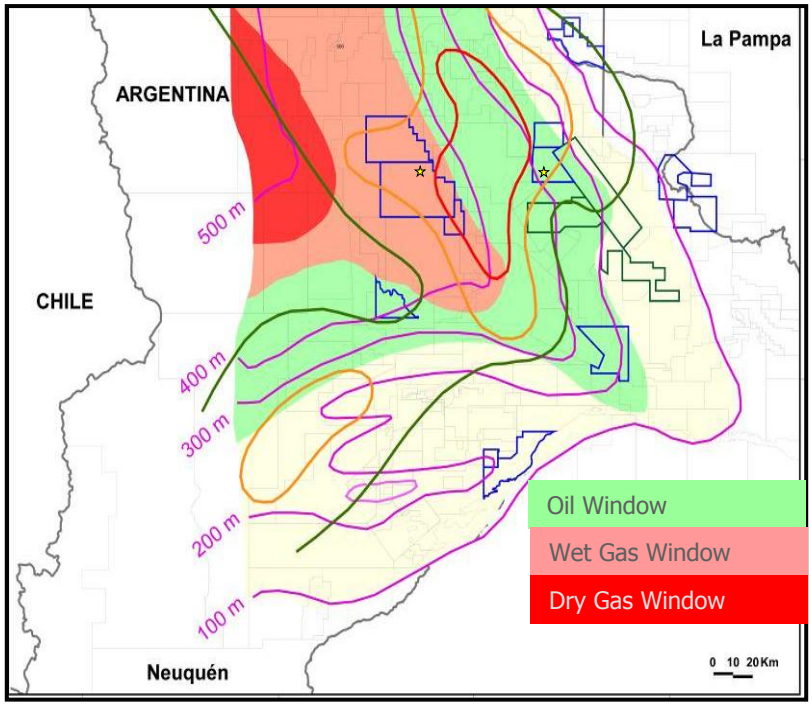


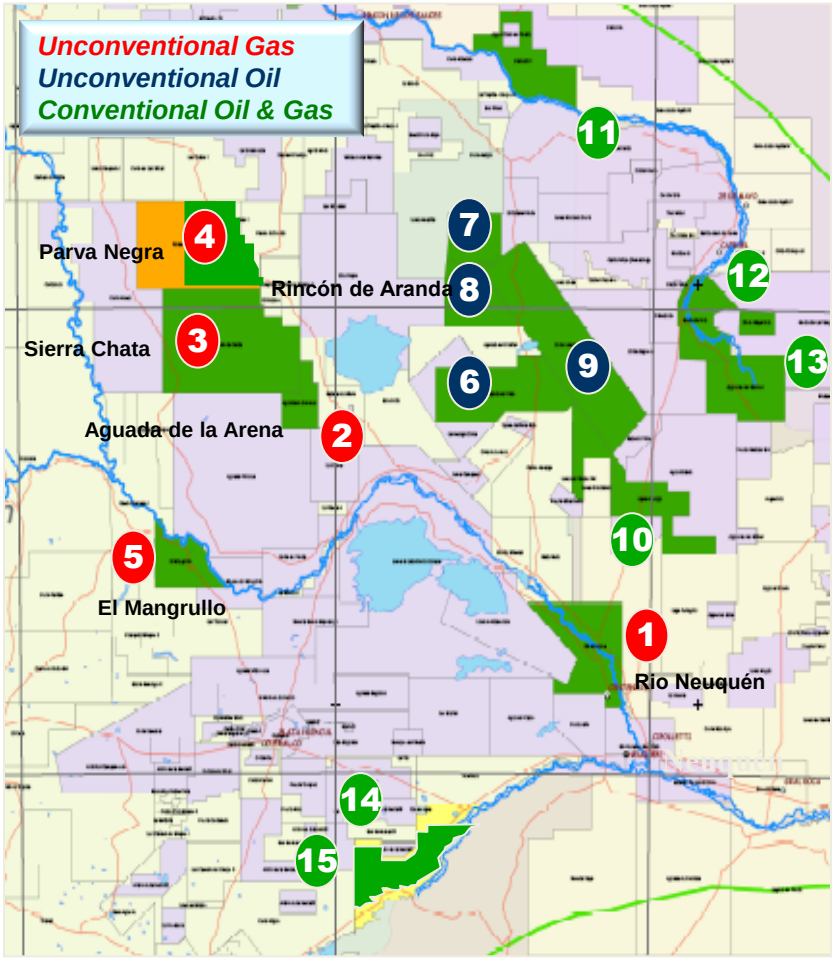
0.622 bi US$ approved in 2014

PESA in the Neuquen Basin

The Vaca Muerta formation compares favorably with analogous ones in the USA, both in terms of thicknesses and in TOC, Reservoir Pressures, Gradient Pressures.

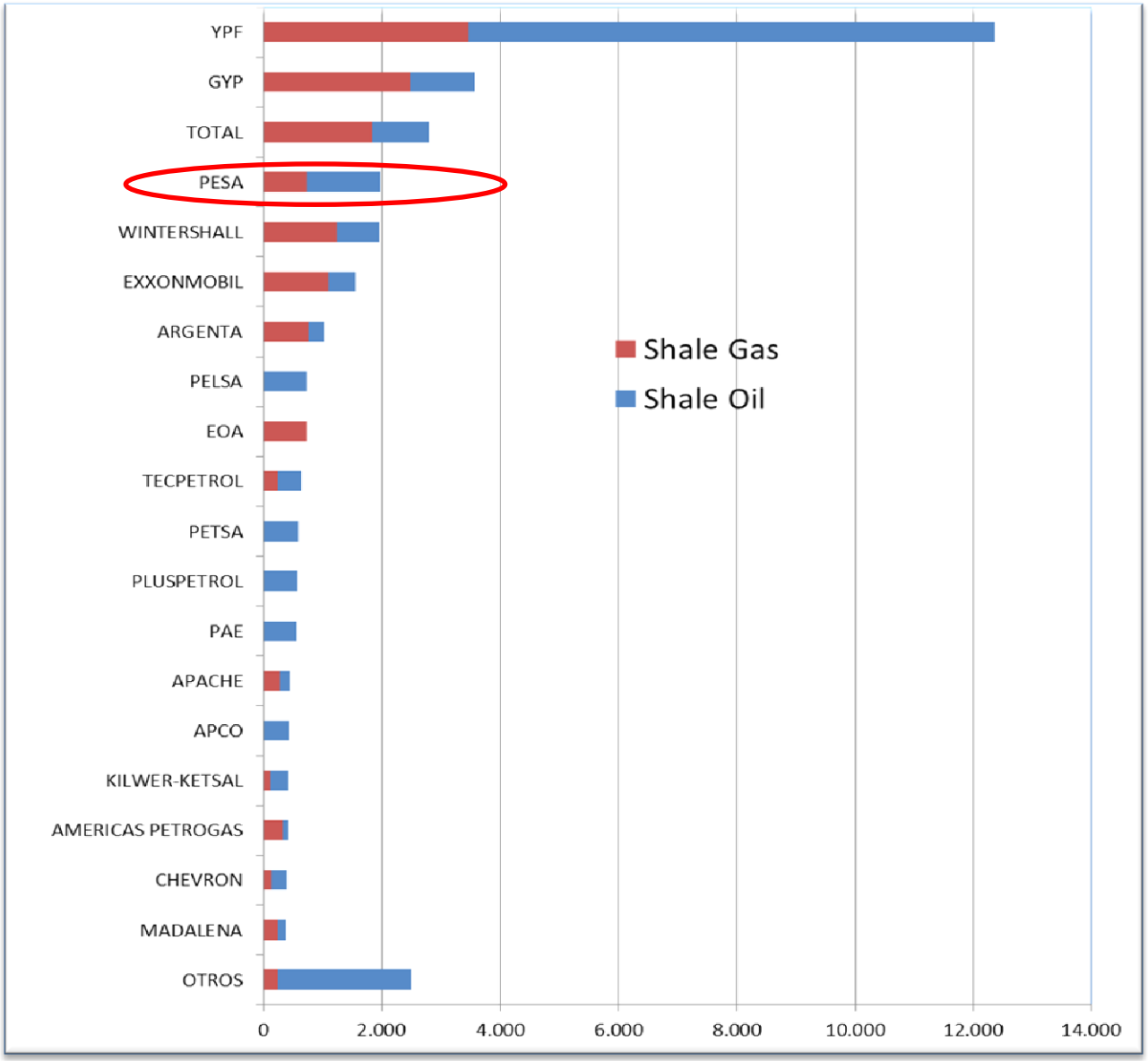
Vaca Muerta Acreage in WI: ~ 7 %





NP-1

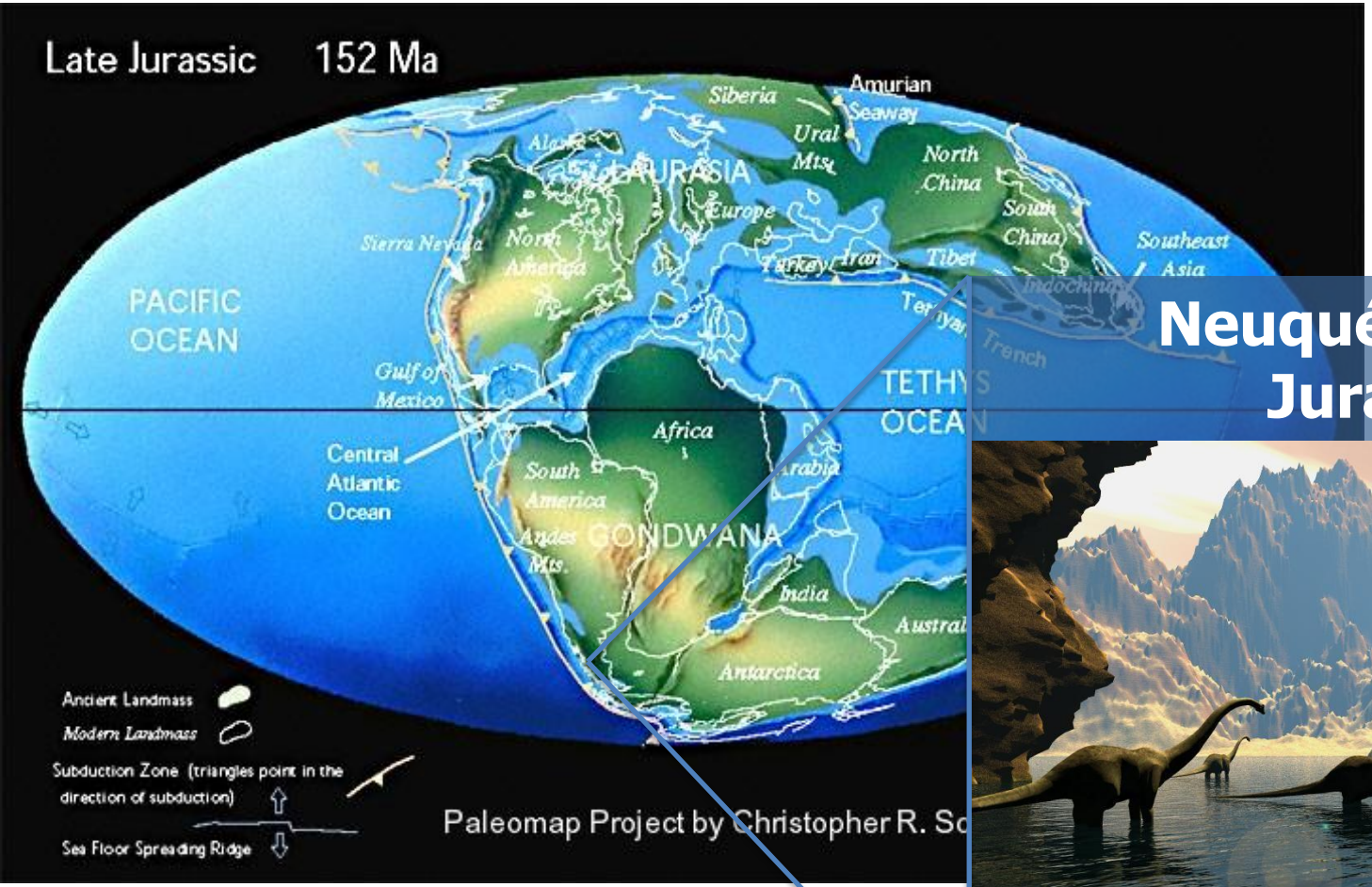
Vaca Muerta – 30,000 Sq km Acreage



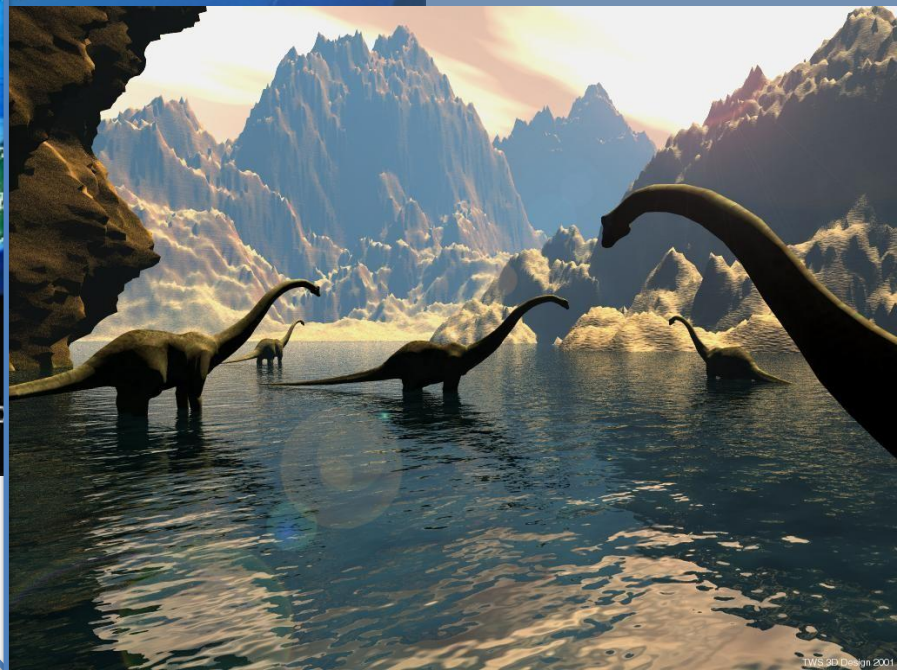
Source - PESA

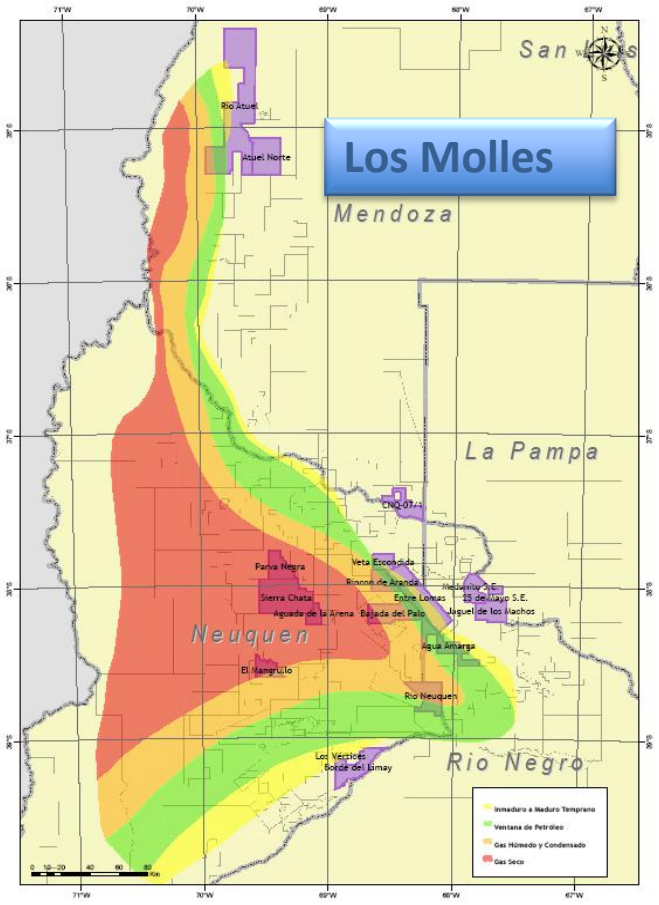
NP-1

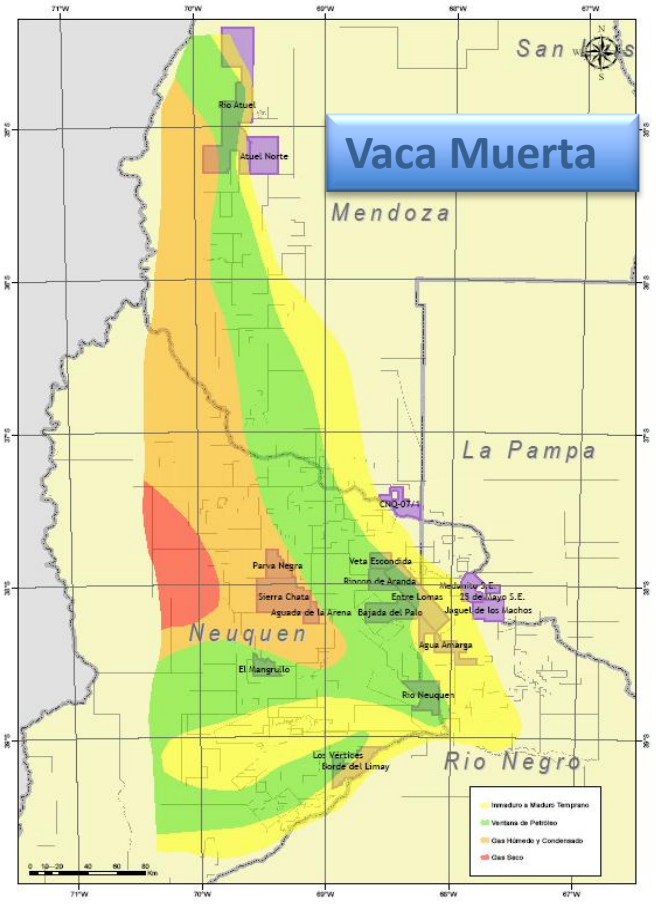
The World 150 million years ago

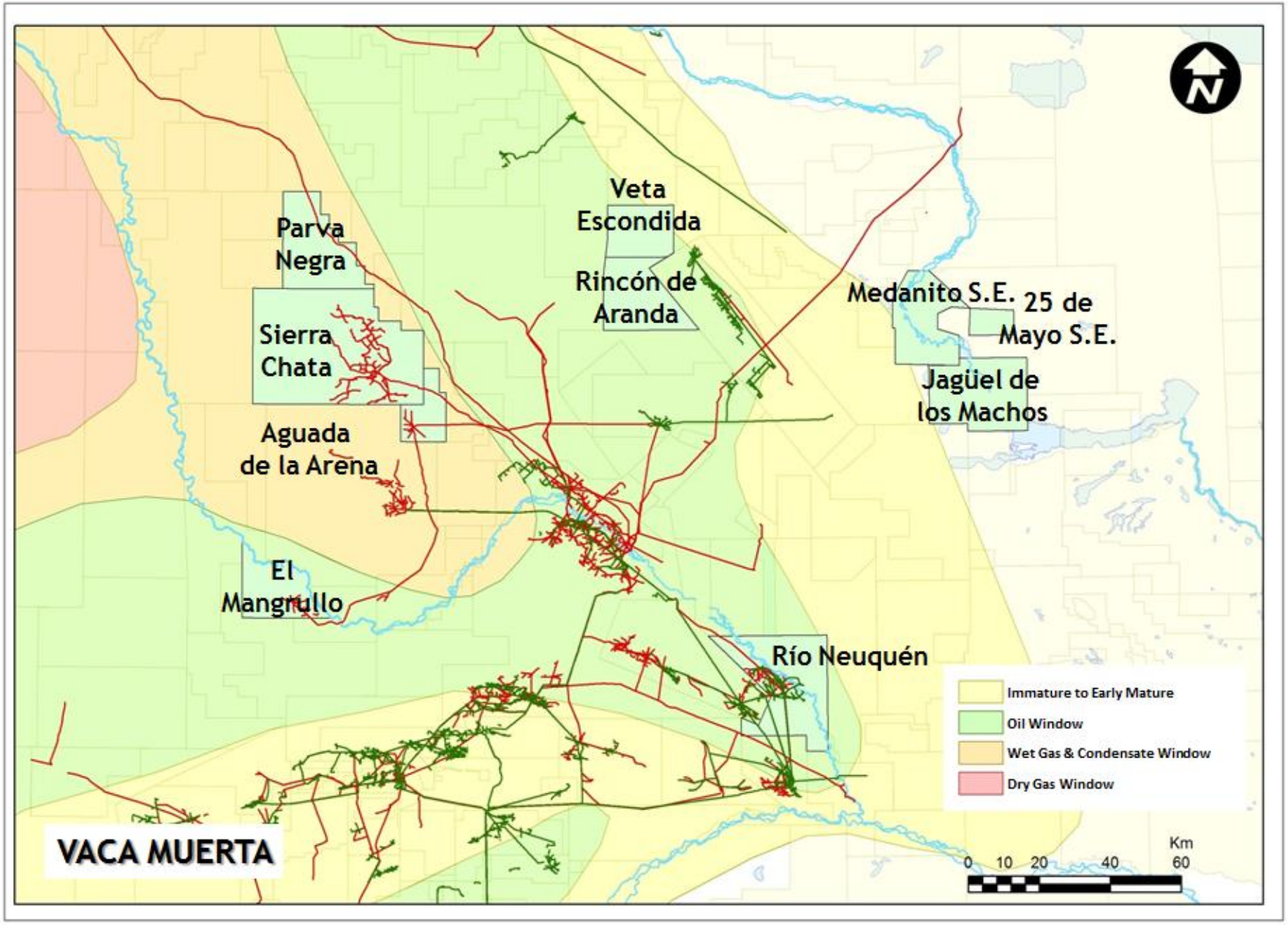


Neuquén in the Jurassic

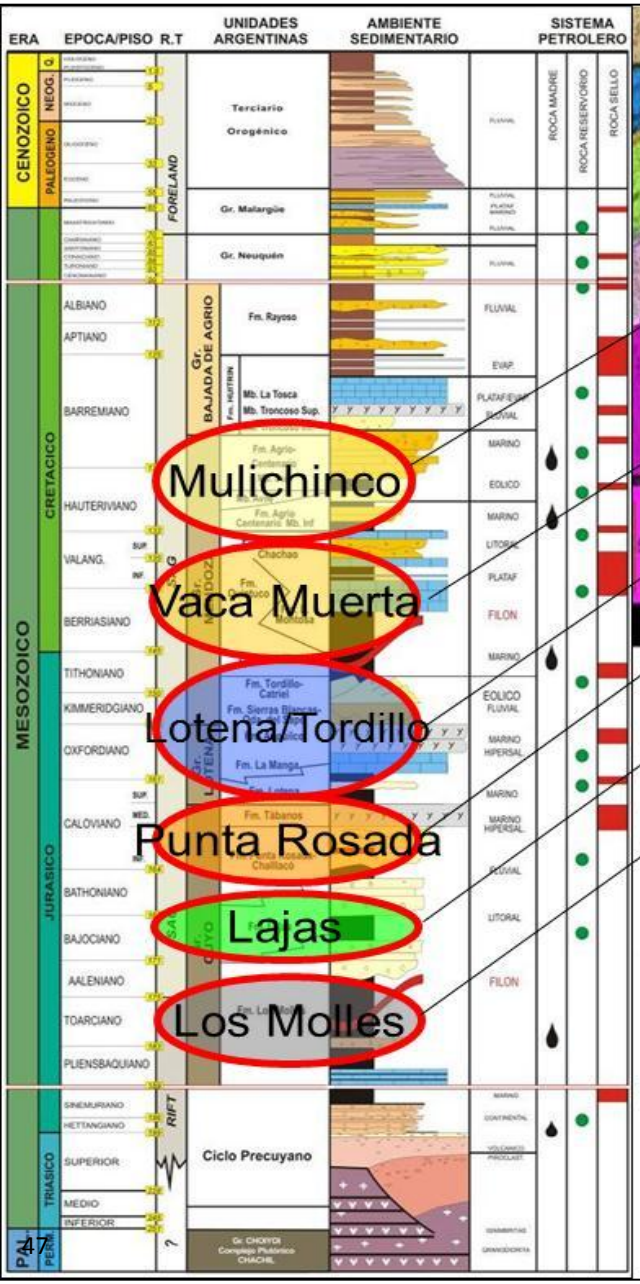


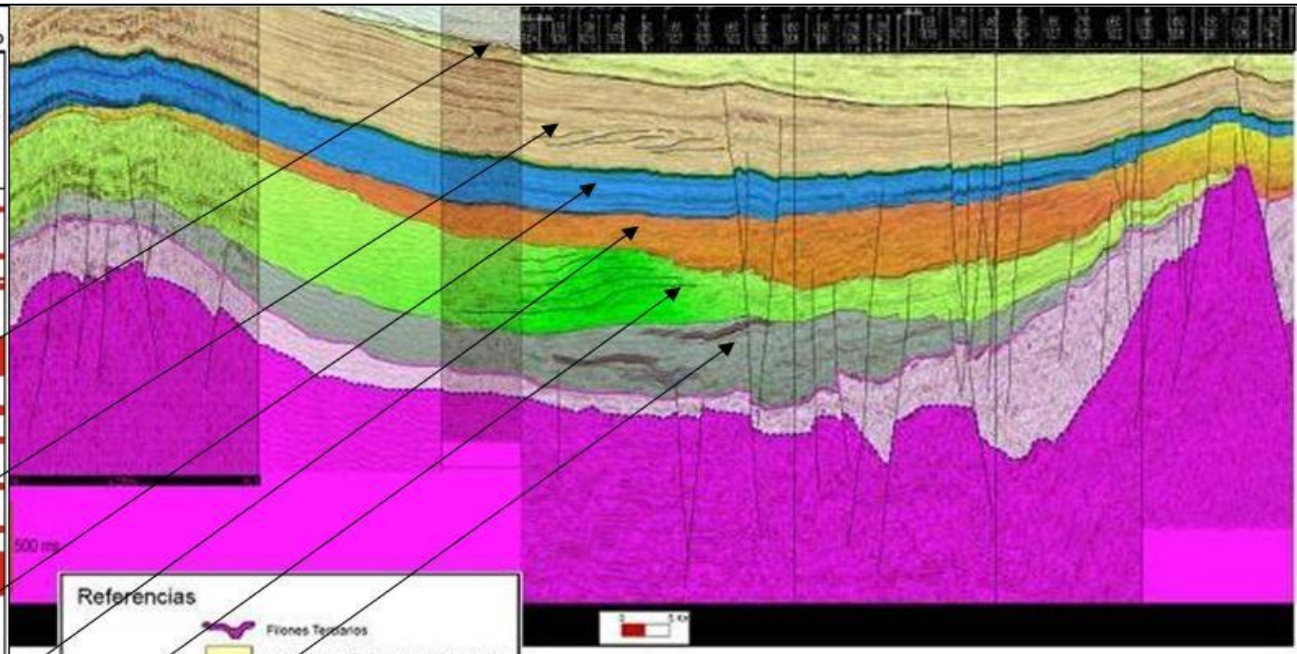

Los Molles
San Luis
Mendoza
La Pampa
Neuquen
Rio Negro
Rio Atuel
Atuel Norte
CNQ-07
Veta Escondida
Rincon de Aranda
Medanito S.E.
Entre Lomas
25 de Mayo S.E.
Parva Negra
Sierra Chata
Aguada de la Arena
Bajada del Palo
Juguel de los Machos
Agua Amarga
El Mangrullo
Rio Neuquen
Los Vertices
Borde del Limay
Inmaduro a Maduro Temprano
Ventana de Petróleo
Gas Húmedo y Condensado
Gas Seco


Vaca Muerta
San Luis
Mendoza
La Pampa
Neuquen
Rio Negro
Rio Atuel
Atuel Norte
CNQ-07
Veta Escondida
Rincon de Aranda
Medanito S.E.
Entre Lomas
25 de Mayo S.E.
Parva Negra
Sierra Chata
Aguada de la Arena
Bajada del Palo
Juguel de los Machos
Agua Amarga
El Mangrullo
Rio Neuquen
Los Vertices
Borde del Limay
Inmaduro a Maduro Temprano
Ventana de Petróleo
Gas Húmedo y Condensado
Gas Seco

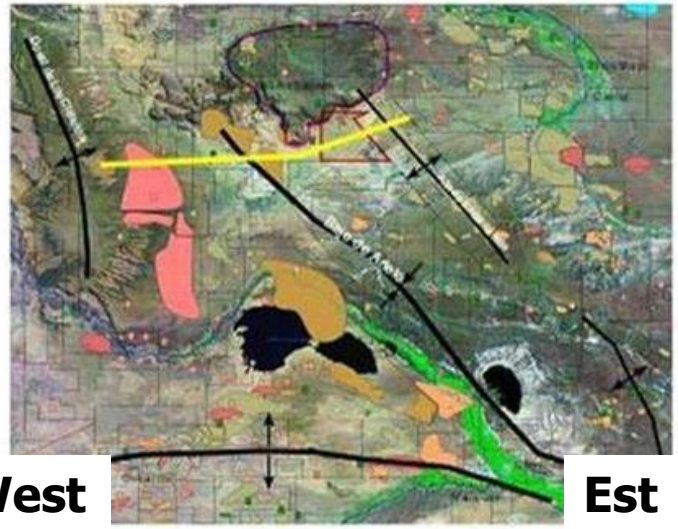

Parva Negra
Sierra Chata
Aguada de la Arena
El Mangrullo
Veta Escondida
Rincón de Aranda
Medanito S.E.
25 de Mayo S.E.
Jagüel de los Machos
Río Neuquén
VACA MUERTA
Immature to Early Mature
Oil Window
Wet Gas & Condensate Window
Dry Gas Window
Km
0 10 20 40 60

NP-1





Several Petroleum Systems

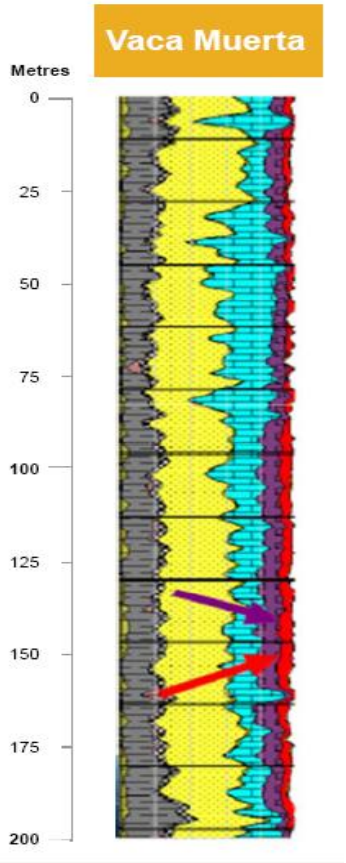


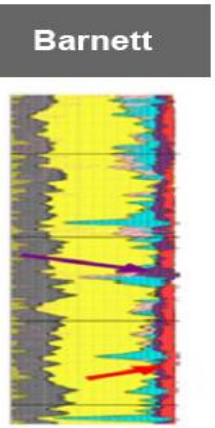
West **Est**

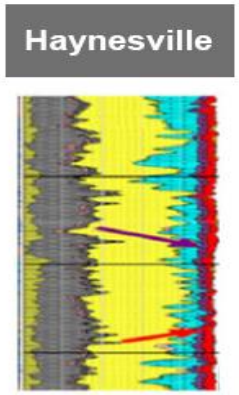
Vaca Muerta analogous

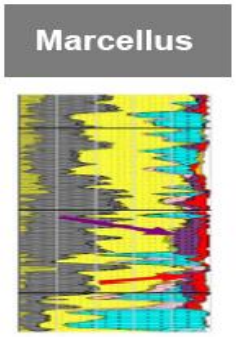
PETROBRAS

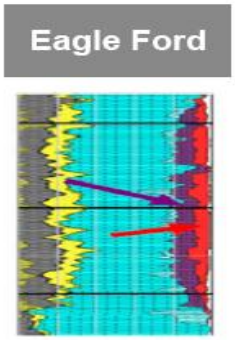
The Vaca Muerta formation compares favorably with analogous ones in the USA, both in terms of thicknesses and in TOC, Reservoir Pressures, Gradient Pressures.

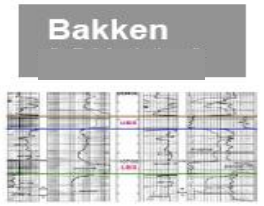












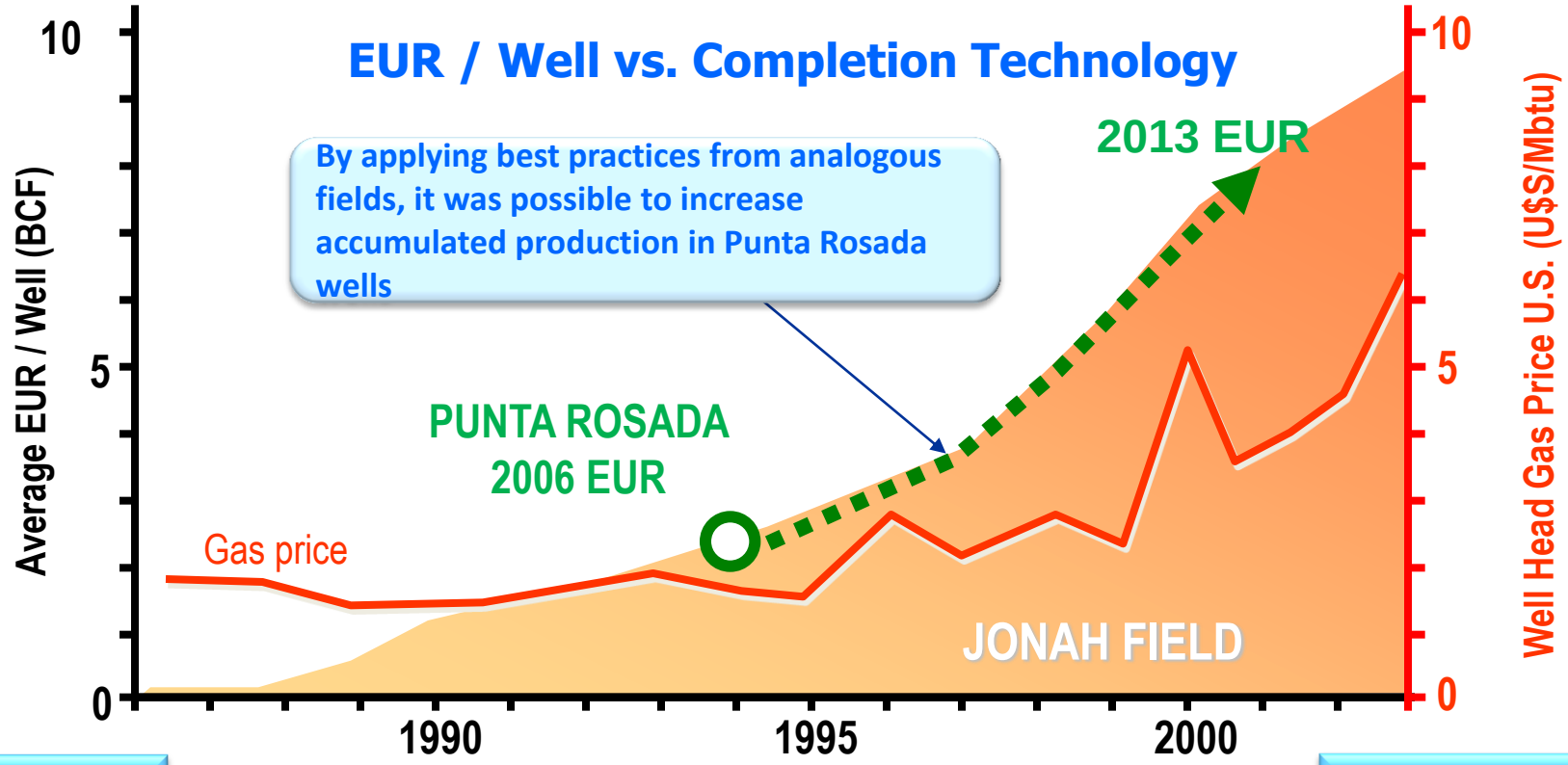
Average Thickness: ~ 60 meters

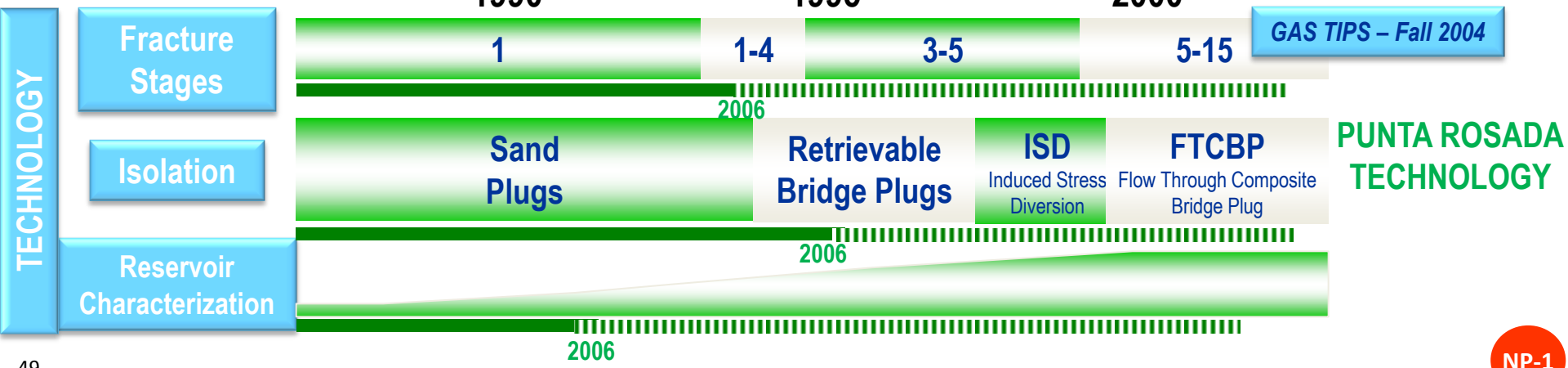
	Vaca Muerta	Barnett	Haynesville	Marcellus	Eagle Ford (*)	Bakken
TOC (%)	5-6	5	2	12	4	12
Thickness (mts)	200 – 300 ..	91	76	61	61	30
Depth(mts)	3.000	2.286	3.658	2.057	2.287	1.829
Area (Km²)	30.000	16.726	23.310	245.773	5.180	51.800
Reservoir pressure (psi)	8.000	3.525	10.800	3.375	4.502	4.200
Pressure gradient (psi/ft)	0,65 - 1,0	0,47	0,90	0,50	0.60	0.70

Source: Shale Oil VM - TGB YPF - Houston.pdf

NP-1

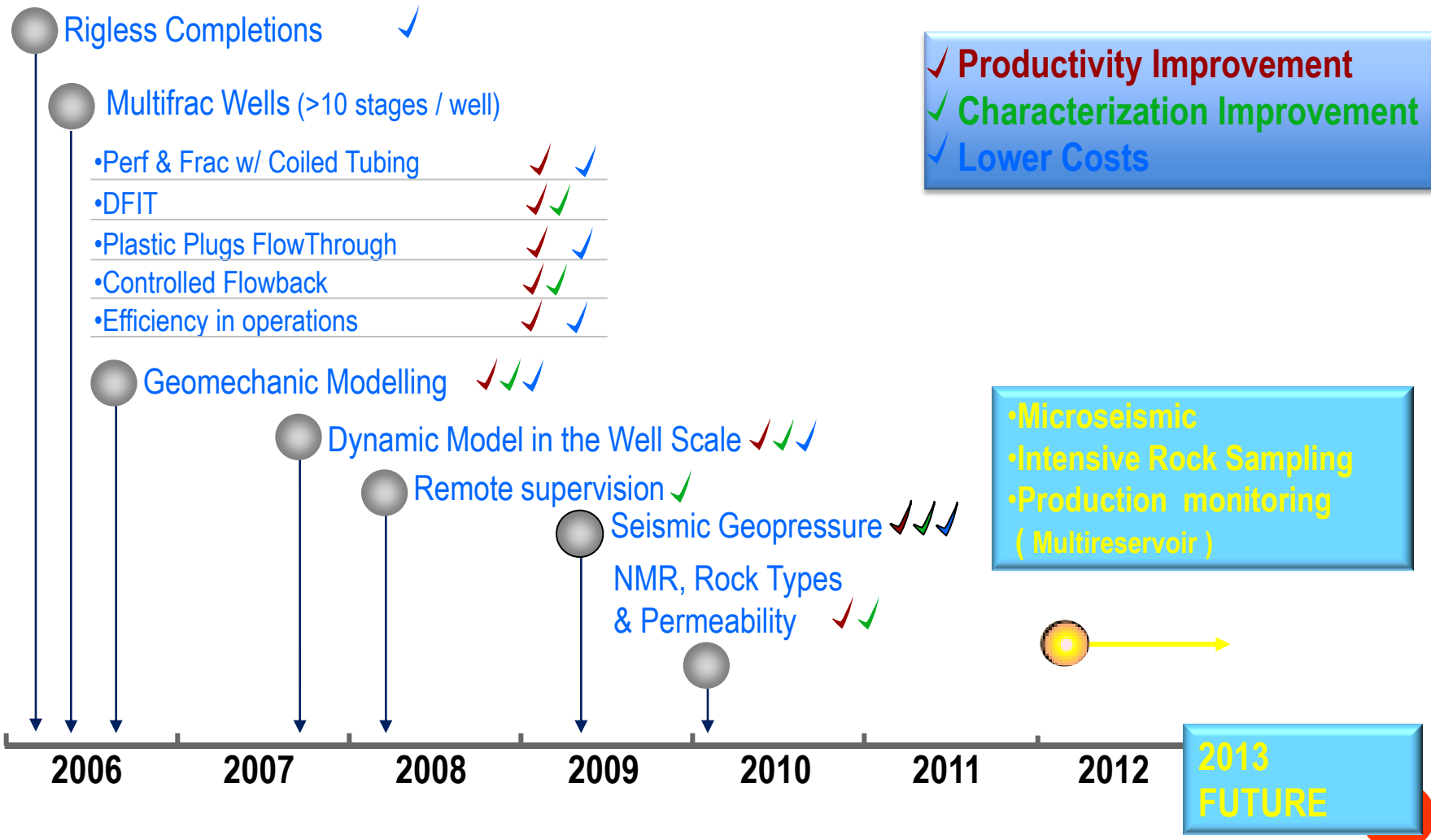
Learning Curve – Tight - Punta Rosada





NP-1

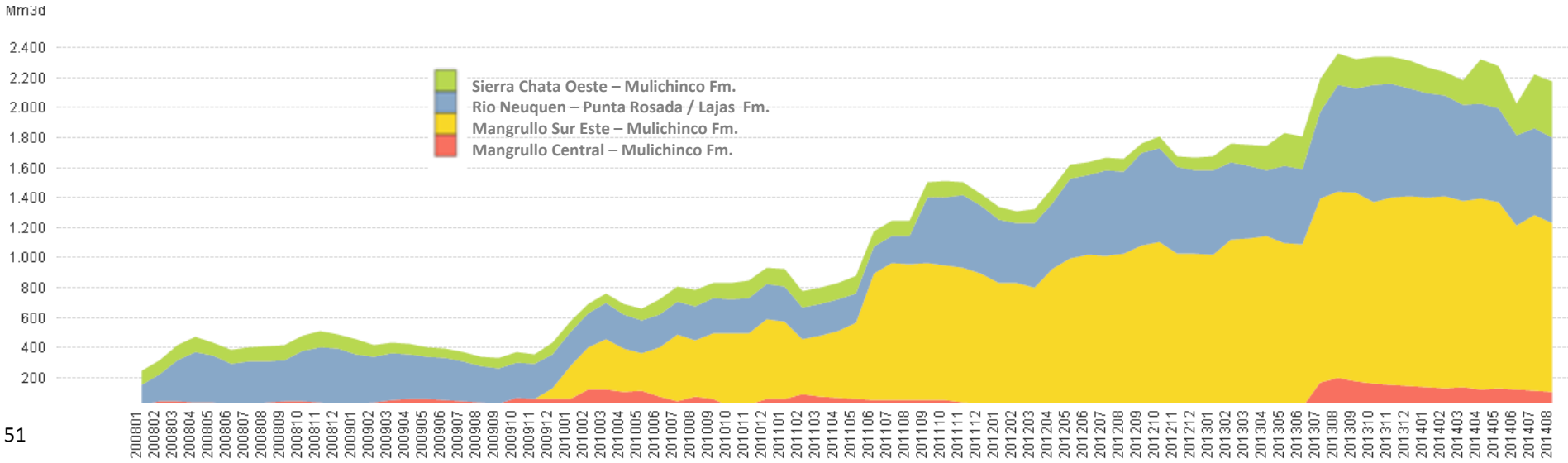
Technology Improvement in The Punta Rosada Project



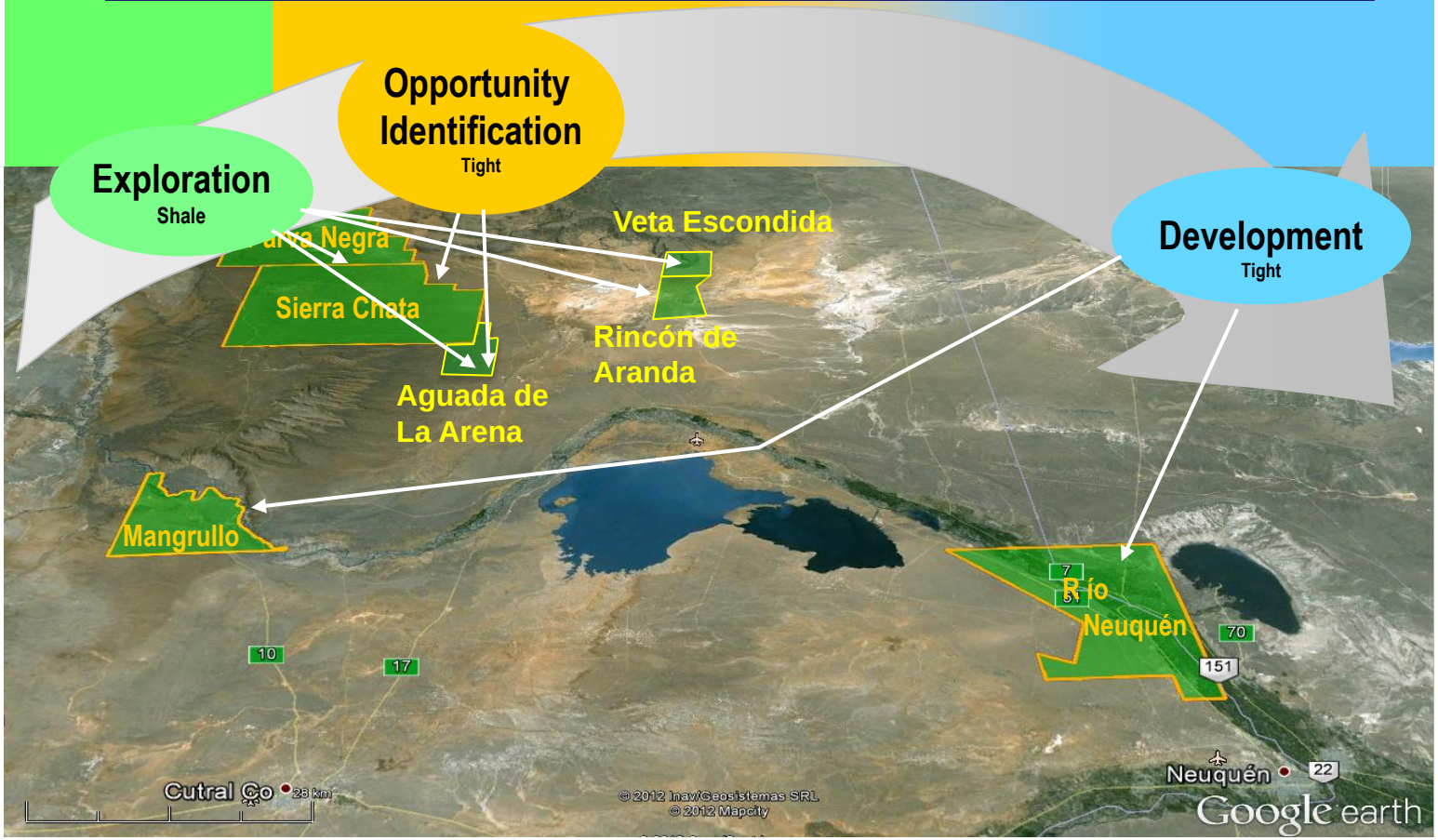
Tight Activities - Petrobras Argentina S.A.

Production August 2014 – Tight Gas (@100%)		
Sierra Chata/Mangrullo / Río Neuquén	Wells in production	Gas Production (Mm^3/d)
Total	**35**	**2.350**

Portfolio Projects 2014 - 18		
Block	**Wells to be drilled**	**Production forecast (Mean @ 100 %)**
Neuquen Basin Gas	**Exploratory: 42 Contingent: 100**	**5.2 MMm^3/d**
Neuquen Basin Oil		**11,300 b/d**



- ANÁLOGOUS FIELD TECHNOLOGIES WORLDWIDE
- WORLD CLASS CONSULTANTS
- SPECIFIC TRAINING
- CENPES – R&D



NP-1

Petrobras Challenges in Vaca Muerta

Petrobras Argentina - Shale Activities

NP-1

The Challenge of Petrobras in Vaca Muerta

- **Reduction of Drilling & Completion Costs ;**
- **To optimize the use of existing infrastructure**
- **To innovate well design optimizing the Stimulated Reservoir Volume (SRV) and maximizing the final recovery of reserves (EUR);**
- **To turn the Neuquen Basin into a school of learning for unconventional exploration and exploitation in the Petrobras System**
- **To go ahead with cooperation strategies to turn Vaca Muerta into SHALE's new global model;**

SPE 149066 - Understanding Volumes, Economics and Risk Mitigation in Unconventional Gas Projects. Shell E&P, 2012.

Source YPF-2014

NP-1

Final Considerations

- **Tight Gas, Shale Oil and Shale Gas give us the opportunity to turn Argentina into a relevant player in Unconventional Resources.**

- **Conventional hydrocarbons decline and continued demand increase define Argentina's energy scenario.**

- **PESA's experience in the development of Tight reservoirs as a basis for Shale study and development (Procap - Pré-salt analogy) optimizing our own acreage and infrastructure.**

NP-1

Final Considerations, cont.

- **Important questions need to be solved in terms of technologies and services:**
  - **Availability.**
  - **Experienced Personnel.**
  - **Long-Term Contracts (Scale) to develop Unconventional Projects.**
  - **Environmental Regulations (Flowback Treatment).**
  - **Logistics.**
  - **We compete with other basins in the world.**
  - **It is necessary to turn this opportunity into richness for the development of Regional Economies.**

Thank you!