Unconventional Resources and the Petrobras Challenges in Argentina*

Tristán Alberto Armaretti1

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1Unconventional 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
Disclaimer


10/12/2014
Tristán Alberto Armaretti
Petrobras Argentina
Dir. E&P/PRNC

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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
Unconventional Resources

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

4
Gas & Oil in the World

Gas (TCF)

- Conventional Resources: 8.842 TCF
- Unconventional Resources: 7.201 TCF
- Unconventional Reserves: 97 TCF

Oil (MMM bbl)

- Conventional Resources: 1.370 MMM bbl
- Conventional Reserves: 1.642 MMM bbl
- Unconventional Resources: 345 MMM bbl
- Unconv. Reserves: N/D

Source: EIA 2013
Argentinean “shale gas,” among the world’s largest
Shale Gas Resources technically recoverable

2013 - World Total: 7.299 TCF

<table>
<thead>
<tr>
<th>Country</th>
<th>Resources (TCF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>China</td>
<td>1.115</td>
</tr>
<tr>
<td>Argentina</td>
<td>802 (11%)</td>
</tr>
<tr>
<td>Algeria</td>
<td>707</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>665</td>
</tr>
<tr>
<td>Canada</td>
<td>573</td>
</tr>
<tr>
<td>Mexico</td>
<td>545</td>
</tr>
<tr>
<td>Australia</td>
<td>437</td>
</tr>
<tr>
<td>South Africa</td>
<td>390</td>
</tr>
<tr>
<td>Russia</td>
<td>285</td>
</tr>
<tr>
<td>Brazil</td>
<td>245</td>
</tr>
<tr>
<td>Poland</td>
<td>187</td>
</tr>
<tr>
<td>France</td>
<td>180</td>
</tr>
</tbody>
</table>

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
Shale Oil Resources technically recoverable

2013 – World Total: 345 billion barrels

<table>
<thead>
<tr>
<th>Country</th>
<th>Reserves (billion barrels)</th>
<th>% of Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russia</td>
<td>75</td>
<td>21.8%</td>
</tr>
<tr>
<td>U.S.A.</td>
<td>58</td>
<td>17.3%</td>
</tr>
<tr>
<td>China</td>
<td>32</td>
<td>9.3%</td>
</tr>
<tr>
<td>Argentina</td>
<td>27 (7,83%)</td>
<td>7.9%</td>
</tr>
<tr>
<td>Lybia</td>
<td>26</td>
<td>7.5%</td>
</tr>
<tr>
<td>Australia</td>
<td>18</td>
<td>5.2%</td>
</tr>
<tr>
<td>Venezuela</td>
<td>13</td>
<td>3.8%</td>
</tr>
<tr>
<td>Mexico</td>
<td>13</td>
<td>3.8%</td>
</tr>
<tr>
<td>Pakistan</td>
<td>9</td>
<td>2.6%</td>
</tr>
<tr>
<td>Canada</td>
<td>9</td>
<td>2.6%</td>
</tr>
</tbody>
</table>

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
Argentina Unconventional Resources (*shale gas*)

- **Vaca Muerta**: 308 TCF
- **Los Molles**: 273 TCF
- **Austral**: 130 TCF
- **San Jorge**: 86 TCF

**Chaco-paranaense**: 3 TCF

*Source: EIA 2013*
Argentina Unconventional Resources (shale gas)

Vaca Muerta

Source: EIA 2013
Argentina Unconventional Resources (*shale gas*)

Loma de la Lata (Conventional)

10,8

308 TCF

Vaca Muerta

Source: EIA 2013
Energetic Consumption

86% of the energy matrix depends on hydrocarbons

- Oil: 35.03%
- Gas: 51.62%
- Renew: 9%
- Coal: 1.5%
- Nuclear: 3%

Source: Secretaría de Energía de la Nación
Gas: Production & Consumption

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.
Porosity and permeability in shales

- 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

- 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

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.

Source: EIA
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.
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.
• 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.

Unconventional Works
Unconventional reservoir
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%
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.

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

* Adicionalmente, en algunos casos se utilizan solventes en cantidades muy bajas, como el gasoil o los aceites vegetales
**Is Fracking Fluid Safe Enough to Drink?**

Colorado Gov. John Hickenlooper drank a glass of Fracking Fluid produced by Oil Giant Halliburton to demonstrate exactly just how safe it is to drink.

According to Halliburton, the fluid is made from "ingredients sourced from the food industry", making it perfectly safe to drink.


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**What Does Fracking Fluid Contain?**

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
<th>Common Applications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water &amp; Sand</td>
<td>99.5%</td>
<td>Swimming pool cleaner, detergent cleaner, household cleaners</td>
</tr>
<tr>
<td>Additives</td>
<td>.5%</td>
<td></td>
</tr>
<tr>
<td>Acids</td>
<td>Helps dissolve minerals and initiate fissure in rock (pre-fracking)</td>
<td>Swimming pool cleaner, household cleaners</td>
</tr>
<tr>
<td>Sodium chloride</td>
<td>Allows a delayed breakdown of the gel polymer chains</td>
<td>Table salt</td>
</tr>
<tr>
<td>Polyacrylamide</td>
<td>Minimizes the friction between fluid and pipe</td>
<td>Soil Conditioner, Water Treatment</td>
</tr>
<tr>
<td>Ethylene Glycol</td>
<td>Prevents scale deposits in the pipe</td>
<td>Automotive anti-freeze, de-icing agent, household cleaners</td>
</tr>
<tr>
<td>Borate salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Household cleaners, laundry detergent, hand soap, cosmetics</td>
</tr>
<tr>
<td>Sodium/Potassium Carbonate</td>
<td>Maintains effectiveness of other components, such as crosslinkers</td>
<td>Washing soda, detergent, soap, water softener, glass, ceramics</td>
</tr>
<tr>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water</td>
<td>Disinfectant, sterilization of medical and dental equipment, cosmetics</td>
</tr>
<tr>
<td>Guar Gum</td>
<td>Thickens the water to suspend the sand</td>
<td>Thickener in cosmetics, baked goods, ice cream, toothpaste, sauces</td>
</tr>
<tr>
<td>Citric Acid</td>
<td>Prevents precipitation of metal oxides</td>
<td>Food additive, food and beverages, lemon juice</td>
</tr>
<tr>
<td>Isopropanol</td>
<td>Used to increase the viscosity of the frac fluid</td>
<td>Glass cleaner, antiperspirant, hair coloring</td>
</tr>
</tbody>
</table>

For more on investing in the American Energy Revolution, visit us at crude.com/invest. 
Use of water resources in The Neuquén Basin

Neuquén River
- 3,153,600,000 m³/year
- 55.7%
- 41.24%
- 2.1%
- 0.76%
- 0.2%
- 0.1%

Limay River
- 6,622,560,000 m³/year
- 98.25%
- 0.1%
- 0.15%
- 0.5%
- 1%
- 1%

Colorado River
- 1,261,440,000 m³/year
- 97.41%
- 0.81%
- 0.8%
- 0.28%

* According to Five-year Plan (2500 wells in 5 years)
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 exceed 100 m.

Maximum induced fracture diameter is 2 to 3 mm.

Most induced fractures run parallel to the surface.
Unconventional Well Layout

- Fresh water aquifer
- Conductor casing
- Surface casing
- Intermediate casing
- Production casing

Horizontal well

- 150 m radius
- Producing formation

Horizontal well fractures

Vertical well

Vertical well fractures
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
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.
Petrobras

&

The Technological Frontier Projects
Deep Water Training Program – PROCAP by Petrobras

<table>
<thead>
<tr>
<th>Year Range</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1986 – 1991</td>
<td>Technological support for Marlim and Albacora’s Production</td>
</tr>
</tbody>
</table>

1,000m (3,300ft)
Oil equivalent production

- PROCAP 1000
- PROCAP 2000
- PROCAP 3000

Year

1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

M boe\(d\)

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

74.4%
8.4%
4.9%
10.6%
Giant Field Discoveries in Campos Basin (80s – 90s)

Garoupa Discovery in Campos Basin (1974)

Pre-Salt - Parati Discovery (2006)

Oil Production since Petrobras creation (1953)
Petrobras in Argentina - PESA
Petrobras Argentina Investments (PESA)

Project Portfolio
2014 - 18
3.94 bi US$

CAPEX

Acquisitions
Exploration
Development

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%
Vaca Muerta – 30,000 Sq km Acreage

Source - PESA
The World 150 million years ago

Neuquén in the Jurassic
Los Molles
Vaca Muerta
Several Petroleum Systems
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

<table>
<thead>
<tr>
<th></th>
<th>Vaca Muerta</th>
<th>Barnett</th>
<th>Haynesville</th>
<th>Marcellus</th>
<th>Eagle Ford</th>
<th>Bakken</th>
</tr>
</thead>
<tbody>
<tr>
<td>TOC (%)</td>
<td>5-6</td>
<td>5</td>
<td>2</td>
<td>12</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>Thickness (mts)</td>
<td>200 – 300</td>
<td>91</td>
<td>76</td>
<td>61</td>
<td>61</td>
<td>30</td>
</tr>
<tr>
<td>Depth (mts)</td>
<td>3.000</td>
<td></td>
<td>2.286</td>
<td>2.057</td>
<td>2.287</td>
<td>4.299</td>
</tr>
<tr>
<td>Area (Km²)</td>
<td>30.000</td>
<td>16.726</td>
<td>92.340</td>
<td>246.773</td>
<td>5.180</td>
<td>51.806</td>
</tr>
<tr>
<td>Reservoir pressure (psi)</td>
<td>8.000</td>
<td>3.525</td>
<td>10.800</td>
<td>3.375</td>
<td>4.602</td>
<td>4.200</td>
</tr>
<tr>
<td>Pressure gradient (psi/ft)</td>
<td>0.65 - 1.0</td>
<td>0.47</td>
<td>0.90</td>
<td>0.50</td>
<td>0.80</td>
<td>0.70</td>
</tr>
</tbody>
</table>

Source: Shale Oil VM - TGB YPF - Houston.pdf
By applying best practices from analogous fields, it was possible to increase accumulated production in Punta Rosada wells.
Technology Improvement in
The Punta Rosada Project

- Rigless Completions ✓
- Multifrac Wells (>10 stages / well)
  - Perf & Frac w/ Coiled Tubing ✓ ✓
  - DFIT ✓ ✓
  - Plastic Plugs FlowThrough ✓ ✓
  - Controlled Flowback ✓ ✓
  - Efficiency in operations ✓ ✓
- Geomechanic Modelling ✓ ✓ ✓
  - Dynamic Model in the Well Scale ✓ ✓ ✓
  - Remote supervision ✓
  - Seismic Geopressure ✓ ✓ ✓
  - NMR, Rock Types & Permeability ✓ ✓

✓ Productivity Improvement
✓ Characterization Improvement
✓ Lower Costs

- Microseismic
- Intensive Rock Sampling
- Production monitoring (Multireservoir)

2013 FUTURE
### Tight Activities - Petrobras Argentina S.A.

#### Production August 2014 – Tight Gas (@100%)

<table>
<thead>
<tr>
<th>Block</th>
<th>Wells in production</th>
<th>Gas Production (Mm³/d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sierra Chata/Mangrullo / Río Neuquén</td>
<td>35</td>
<td>2.350</td>
</tr>
</tbody>
</table>

#### Portfolio Projects 2014 - 18

<table>
<thead>
<tr>
<th>Wells to be drilled</th>
<th>Production forecast (Mean @ 100 %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neuquen Basin Gas Exploratory: 42</td>
<td>5.2 MMm³/d</td>
</tr>
<tr>
<td>Neuquen Basin Oil Contingent: 100</td>
<td>11,300 b/d</td>
</tr>
</tbody>
</table>
ANÁLOGOUS FIELD TECHNOLOGIES WORLDWIDE

WORLD CLASS CONSULTANTS

SPECIFIC TRAINING

CENPES – R&D

Opportunity Identification
Tight

Exploration
Shale

Development
Tight

Mangullo

Rincón de Aranda

Aguada de La Arena

Sierra Chata

 área Negra

Veta Escondida

Rincón de Aranda

Neuquén

Google earth
Petrobras Challenges in Vaca Muerta
Petrobras Argentina - Shale Activities
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;

Source YPF-2014
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.
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!