Cerro Dragón: History and Future Challenges for an Integrally Managed Field*

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Abstract

The Cerro Dragón Field, covering 860,000 acres, was acquired in 1958 from Amoco and produces oil and gas using primary and secondary water injection. The waterflood was started in 1969, and since 2008 there were about 200 wells drilled per year, with a current total of 3190 producers and 647 injection wells.

Production is from Middle to Late Cretaceous fluvial and alluvial (braided stream) sandstones with an average of 20% porosity and 10-50 mD. Individual reservoirs of 3-15 feet thick are stacked to 600 to 1200 feet vertically, each having different fluid contacts. Due to the high clay content, the reservoir is sensitive to formation damage. The trap is combination structural (tilted horst blocks and faulted anticlines) and stratigraphic (pinchouts). Formation water is low salinity (<4000 ppm), and oil is 20-30 API with high viscosity (20 cp).

Summary

• Pan American Energy has made a significant investment effort in exploration, development, infrastructure and technology. Cerro Dragon is today one of the most productive areas in Argentina with more than 1 billion barrels of accumulated oil.

• Cerro Dragon is a mature field, discovering new opportunities based on studies and technology application.

• Waterflooding is one of the key drivers for production increase and reserves replacement.

• 75% of Cerro Dragon is under waterflooding. Injection volumes exceed 170 Mm3/d (1 MMbbl/d). All produced water is treated and re-injected.

• The challenge is to continue developing water flood projects and to increase recovery factors through studies and new technology application, managing complexity and uncertainties.
References Cited


Cerro Dragón
History and Future Challenges for an Integrally Managed Field

Javier E. Gómez (Pan American Energy LLC)
Intracratonic Basin related to Atlantic Opening

General Description

- Acquisition Date: 1958 (Amoco)
- Area: 860,000 acres
- Produces by primary and secondary (water injection)
- Gas production

WF started in 1969
- 3190 prod & 647 inj
- Two hundred wells (200) per year have been drilled since 2008
Reservoir: Mid to late Cretaceous sandstones. **Average 20% porosity, 10-50 md permeability.** High clay, lithic content **sensitive to formation damage.** Environment of Deposition: **Fluvial** and **alluvial** braided stream. Migration through faults.

Trap: Tilted horst blocks, faulted anticlines, combination **structural/stratigraphic,** stratigraphic pinchouts.

Pay Distribution: **600’ to 1200’ stacked** individual reservoirs **3’ to 15’ thick,** each with different fluid contacts. **Wells require stimulation** to break past formation damage caused during drilling and testing.

Fluid: **low salinity** (<4,000 ppm) fm water, 20-30 API, **high viscosity** 20 cp.
Production & Reserves

Argentina Daily Production
(Feb 2015)

- **Oil**: 529 kbopd
  - 263 kbopd (50%)
  - CD: 96 kbopd (37%)
- **Gas**: 4,07 bcfgd
  - 0.54 bcfgd (13%)
  - CD: 0.3 bcfgd (56%)

Argentina Proved Reserves@2013
(Nat. Sec. of Energy)

- **Oil**: 2330 mmbbl
  - 1580 mmbbl (68%)
  - CD: 905 mmbbl (57%)
- **Gas**: 11,6 tcf
  - 1.7 tcf (15%)
  - CD: 1.1 tcf (65%)
Waterflooding Progression

**Cerro Dragón Area**

Oil Secondary Production & Water Injection

- **1969 – 1978**
  - 56 Injectors
  - 15,000 m³/d water injection
  - 500 m³/d oil
  - 3 projects

- **1979 – 2001**
  - 212 Injectors
  - 48,000 m³/d water injection
  - 2,500 m³/d oil
  - 33 projects

- **2002 – 2004**
  - 369 Injectors
  - 94,000 m³/d water injection
  - 5,500 m³/d oil
  - 45 projects

- **2005 – 2009**
  - 450 Injectors
  - 132,000 m³/d water injection
  - 7,500 m³/d oil
  - 49 projects

- **2010 – 2013**
  - 582 Injectors
  - 159,000 m³/d water injection
  - 7,800 m³/d oil
  - 57 projects

- **2014**
  - 642 Injectors
  - 169,500 m³/d water injection
  - 8,061 m³/d oil
  - 65 projects

**Waterflooding Progression**

- **1969 to 1978**
  - Mechanical Packers
  - 1 to 4 zones

- **1978 – 2000**
  - Mechanical Packers
  - 7 zones

- **2000 – 2004**
  - Mechanical & Hydraulic Packers
  - 3 stages – 13 zones

- **2004 – 2011**
  - Hydraulic Packers
  - 3 stages – 20 zones

- **65 Proyectos de Rec Secundaria**
  - Injection: 169,500 m³/d
  - Productive Wells: 2162
  - Injection Wells: 642
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Time structure

- Selective injection (up to 20 mandrels per well)
- Well head pressure measurement
- Injection rate measurement by layer
- Water quality control
**Injection Conformance**

¿What does Conformance mean?

It is said that water injection is *on conformance* when it is injected the defined rate in the corresponding layer. Injection rate comes from the simulation study.

¿Why we consider it important?

Conformance computation and monitoring is an important surveillance tool to detect deviations, assure a good waterflooding management and an efficient swept.
Waterflooding Studies

Through a WF Common Value Process, using an Analytical Simulation
Waterflooding Studies

- Handles incompressible fluid displacement, therefore contemplates no transients pressure changes.
- Oil saturation of each reservoir depends on its evolution and past production mechanism.
- Saturation is considered homogeneous inside flow element and it evolves inside the element during the WF development.
- Delayed response by the presence of an initial gas saturation is modeled by empirical filling curve that depends on the initial saturation of gas.
WF Studies Results
Water Injection Growth Plan

Average WI Growth 13000 m3/d per year
New Facilities: Water Injection Plants and Batteries
Water Injection Facilities

Injection Plant is designed for full capacity, but it is constructed by stages (8000 m3/d each) according to waterflooding projects expansion.
TargeT Logging

- Define the reservoir dynamic behavior producing all together
- Identify the layers with high WOR
- Evaluate the production of perforated layer without test, evolution of stimulated zones and detect possible future stimulations
- Identify cross flow in static/dynamic conditions
- Determine if the cemented layers are still hermetic
- Obtain information for WF Surveillance

- 12-18 perforated zones
- Water Cut > 95%
- Each zone placed on production test

This is the 1st time PLT Data can be recorded in wells that don’t flow naturally in 5 ½” casings
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**TargeT Logging**

<table>
<thead>
<tr>
<th>Zones</th>
<th>Qw res. m3/D</th>
<th>Qg res. m3/D</th>
<th>Qg res. m3/D</th>
</tr>
</thead>
<tbody>
<tr>
<td>E5(1974-4-2722)</td>
<td>22.54</td>
<td>-0.42</td>
<td>1.8</td>
</tr>
<tr>
<td>F6(1980-4-1950)</td>
<td>40.35</td>
<td>0.49</td>
<td>1.9</td>
</tr>
<tr>
<td>H10a(1992-5-1996)</td>
<td>29.09</td>
<td>-0.66</td>
<td>0.41</td>
</tr>
<tr>
<td>I4b(2041.5-2044.5)</td>
<td>2.72</td>
<td>-0.22</td>
<td>-1.30E-2</td>
</tr>
<tr>
<td>M3a(2446.8-2455.9)</td>
<td>74.74</td>
<td>3.89</td>
<td>1.61</td>
</tr>
<tr>
<td>M6b(2497.5-2499.5)</td>
<td>-1.74</td>
<td>0.00</td>
<td>0.00</td>
</tr>
</tbody>
</table>

Well log analysis showing water, oil decline, and WOR (water-oil ratio) over the years 2010 to 2012.
### Pulsating Injection

PPT produces a pulsing injection that dilates the matrix pore space through an elastic response. It causes not only the current pore network to increase in porosity and permeability but also opens up additional pore spaces to liquid flow.

Therefore, Pressure Pulses can enhance the water conformance, reduce the front instabilities and overcome capillary.

- **Injection range:** from 40 to 1600 m³/d.
- **Setting:** in the tool in front of the layer with connection cable up to the surface (WO operation).
- **Frequency adjustment:** from the Surface Panel from 10 to 20 pulse/min.
- **Pressure range:** from 250 to 1500 psi.

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**Electric Model**

- OD 9.5 cm (3.75 in)
- 120 cm (47.2 in)
- Tool Zero

**Mechanic Model**

- OD 4.3 cm (1.70 in)
- 79 cm (31.1 in)
- Tool Zero

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**Injection range:** from 40 m³/d to 240 m³/d.

**Setting:** in the tool in front of the layer, hung on the tubing nipple (WL operation).

**The operation frequency auto-adjusts in relation with the pressure difference between the reservoir pressure and WHBP.**
**Pulsating Injection**

- The layer E1 has individual injection.
- E1 has the best cumulative oil and cumulative water injection in the zone.
- So 57 %.
- Good connectivity producers – injectors, without barriers or faults.
- Low current Recovery Factor = 7.5 % (prim + sec).

- Isolated geological block.
- Individual oil test without fracture job.
- Low pressure water admission (200 psi).
- 30 days Tracer Transit Time (between injector and producer)
Pulsating Injection Pilot Results

![Graph showing Qo [m³/d] over time with Project, Qo historico, Linea Base, Pronóstico, con WaveFront, and con WaveFront lines.]

![Graph showing WOR [m³/m³] over time with Project.]
EOR

- Bright Water gel treatment in 7 injection wells
- 15 associated producers inside the patterns
- 24 layers treated

- Production response underperformance (after 18 months)
- BW treatment volume could be less than the needed
- Only one fall off test showed some change in flow path after treatment
- Some mechanical problems impacted injection
- Opportunities: Better static and dynamic characterization, BW volume estimation, economic feasibility
Cyclic Injection

- The methodology pretends to take advantage, through a secondary recovery process, of viscous as well as capillary drives
- Improve production efficiency, reducing WOR
- Reduce the volume of injected water for the development of the plan
- Improve the final recovery factor
  - 10 injector wells
  - 22 producer wells
  - Average WOR before project: 20 (Wcut: 95%)
  - Annual oil decline: 7%

<table>
<thead>
<tr>
<th>Project</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pore Volume of the block (thousand barrels)</td>
<td>29,514</td>
</tr>
<tr>
<td>Initial Oil Saturation</td>
<td>0.43</td>
</tr>
<tr>
<td>Initial Water Saturation</td>
<td>0.57</td>
</tr>
<tr>
<td>Residual Oil Saturation</td>
<td>0.27</td>
</tr>
<tr>
<td>Mobile Oil Saturation</td>
<td>0.16</td>
</tr>
<tr>
<td>Mobile Oil (reservoir thousand barrels)</td>
<td>4,724</td>
</tr>
<tr>
<td>Injected Water to Date (thousand barrels)</td>
<td>59,529</td>
</tr>
<tr>
<td>Injected Water to Date in PV</td>
<td>2</td>
</tr>
<tr>
<td>Injected Water to Date in MOVs</td>
<td>12.6</td>
</tr>
</tbody>
</table>
Results show that it is possible to take advantage of capillary forces, without giving up the benefits of viscous drive.

Cyclic Injection reduces to a great extent the power consumption, by managing much smaller volumes of injected water and with less produced fluid. Volumes of water not injected in the closure cycle can be used for flooding new reservoirs in the same project or in neighboring zones.
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Thank you!!