Brazilian Pre-Salt & Libra: Overview, Initial Results & Remaining Challenges

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Non-sec compliant oil and gas reserves:

cautionsary statement for us investors

We present certain data in this presentation, such as oil and gas resources, that we are not permitted to present in documents filed with the United States Securities and Exchange Commission (SEC) under new Subpart 1200 to Regulation S-K because such terms do not qualify as proved, probable or possible reserves under Rule 4-10(a) of Regulation S-X.
Agenda

1. Brazilian Pre-Salt
   - Overview
   - Main Challenges & Technological Solutions
   - Initial Results

2. Libra
   - Overview
   - Main Exploratory Data
   - Information Acquisition Plan
   - Main Technical Challenges & Opportunities
   - Way Forward & Final Message
1. Brazilian Pre-Salt

Overview

Main Challenges & Technological Solutions

Initial Results

2. Libra

Overview

Main Exploratory Data

Information Acquisition Plan

Main Technical Challenges & Opportunities

Way Forward & Final Message
Campos Basin
7,000 km$^2$
(1.7 million acres)

Santos Basin Pre-Salt
15,000 km$^2$
(3.7 million acres)

City of Moscow
6x

Pre-Salt Size
Pre-Salt Geological History

164 MY
Pre-Salt Geological History

152 MY
Pre-Salt Geological History

130 MY
Pre-Salt Geological History

122 MY
Pre-Salt Geological History
Pre-Salt Geological History
Pre-Salt Geological History

Nowadays
Recent Stromatolites
Lagoa Salgada, RJ, Brazil

Recent Stromatolites
Shark Bay, Australia
Pre-Salt Reservoirs | Getting There
Petrobras Evolution | From Post-Salt to Pre-Salt

Mount Everest (8.8km)

PRE SALT
(Reservoirs up to 7km)
1. Brazilian Pre-Salt

Overview

Main Challenges & Technological Solutions

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Main Technical Challenges & Opportunities

Way Forward & Final Message
Presence of contaminants (CO$_2$ and H$_2$S) in the reservoirs

Ultra-deep waters / long distance to shore (~300 km)

Thick salt layer & very deep reservoirs

Very heterogeneous carbonate reservoirs & seismic imaging complexity
Overall Strategy: Phased Development

Phase 0 Data acquisition 2008/2013
- Exploratory and appraisal wells
- EWTs
- Pilot systems

Phase 1 Operating production > 1MM bbl/d 2014/2020
- FPSO families adapted to pre-salt scenario
- Standardization
- Repeatability

3 Pilot Projects

18 Definitive Systems
- High density, full azimuth seismic acquisition (world record: 21,700 km²)
- Intensive use of seismic attributes
- Highly detailed characterization of poorly-known microbial carbonate reservoirs
- Lab testing & numerical modelling of complex recovery mechanisms, such as WAG
- First use of WAG in ultra-deep waters (2,200 m)
- Flexible / robust drainage plans
- High level standards for HSE
- Learning curve approach in well design and construction
- Adoption of 5th and 6th generation rigs
- Intensive use of specialized vessels
- High angle wells, build up in the salt layer
- Water depth record (2,249 m) for a subsea well drilled with Pressured Mud-Cap Drilling (PMCD)
- Intensive use of intelligent completion -12 wells with this system installed
Flow Assurance

- 9 5/8” intelligent completion with down hole chemical injection
- Adoption of thermal insulation to prevent wax
- Subsea layout to mitigate hydrates formation
- Operational success in the first WAG cycles in Lula Field
Mix of rigid and flexible lines: qualification of new gathering systems for pre-salt scenario

Deepest flexible riser installed in Lula field (2,220 m)

New design for WAG manifold

Subsea flexibility for reservoir drainage plans

Development of pre-salt 10kpsi X-trees, with standard mechanical interfaces
Topside Facilities

- Use of standards FPSO: VLCC hulls with maximum electric energy generation of 4 x 25 MW
- Flexibility to handle variables concentration of contaminants (mainly CO$_2$ and H$_2$S)
- CO$_2$ separation and reinjection in the reservoir
- Development of local suppliers
CAPEX (2014 – 2018)

**Total CAPEX**
- **Production Development**: US$ 112,5 billion (73%)
- **Exploration**: US$ 23,4 billion (15%)
- **Infrastructure & Support**: US$ 18,0 billion (12%)

**Production Development + Exploration**
- **Post Salt**: US$ 53,9 billion (40%)
- **Pre Salt**: US$ 82,0 billion (60%)

**E&P Petrobras**
- US$ 153,9 billion (77%)

**E&P Partners**
- US$ 44,8 billion (23%)

**Total with Partners**
- US$ 198,7 billion (100%)
1. Brazilian Pre-Salt

Overview

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Way Forward & Final Message
Main Results: Great Reduction of Average Well Construction Time

- Average construction time decreased by more than 60% since 2010
- Drilling and Completion percentages for 2010 to 2014:
  - 2010: 100%
  - 2011: 60%
  - 2012: 90%
  - 2013: 80%
  - 2014: 45%

**TIMELINE AND TECHNOLOGICAL MILESTONES**

- **2010**: First wells completed
- **2011**: Mechanical completion for 2 intervals

Great Reduction of Average Well Construction Time
Main Results: Great Reduction of Average Well Construction Time

Average construction time decreased by more than 60% since 2010

- Drilling
- Completion

-60% -65%

TIMELINE AND TECHNOLOGICAL MILESTONES

2010 2011 2012 2013 2014

Bit Design, BHA (Bottom Hole Assembly) and Fluid Optimization
First Results Achieved
Main Results: Great Reduction of Average Well Construction Time

Average construction time decreased by more than 60% since 2010

- Drilling
- Completion

-60%
-65%

TIMELINE AND TECHNOLOGICAL MILESTONES

2010 2011 2012 2013 2014

First Horizontal Well

Main Results: Great Reduction of Average Well Construction Time

Average construction time decreased by more than 60% since 2010

- Drilling
- Completion

-60%
-65%

TIMELINE AND TECHNOLOGICAL MILESTONES

2010 2011 2012 2013 2014

First Horizontal Well
Main Results: Great Reduction of Average Well Construction Time

**Average construction time decreased by more than 60% since 2010**

- **Drilling**
- **Completion**

### TIMELINE AND TECHNOLOGICAL MILESTONES

- **2010**
  - MPD/PMCD in Floating Rigs to drill in ultra-deep waters
  - Intelligent Completion for 9 ⅝” casing

- **2011**

- **2012**

- **2013**

- **2014**
TIMELINE AND TECHNOLOGICAL MILESTONES

Well construction record: 92 days

Injector Well

Completion Design Simplification

Dual Derrick Rig Optimization

SESV for installing PAB and XT

Main Results: Great Reduction of Average Well Construction Time

Average construction time decreased by more than 60% since 2010

-60%

-65%

Drilling

completion
Campos Basin
Pre-Salt first oil
Jubarte field (EWT)
P-34

Daily record: 581 thousand bopd

August 2014
Cumulative Production
414 million boe

Production from Pre-Salt Reservoirs Operated by Petrobras
Santos Basin
Pre-Salt first oil
Lula field (Tupi lead) - EWT FPSO BW Cid. São Vicente

Daily record: 581 thousand bopd

CUMULATIVE PRODUCTION
414 million boe

Production from Pre-Salt Reservoirs Operated by Petrobras
Production from Pre-Salt Reservoirs Operated by Petrobras

Santos Basin
First definitive production system
Lula field pilot
FPSO Cid. Angra dos Reis

Daily record: 581 thousand bopd

CUMULATIVE PRODUCTION
414 million boe

Production from Pre-Salt Reservoirs Operated by Petrobras

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CUMULATIVE PRODUCTION
414 million boe
Production from Pre-Salt Reservoirs Operated by Petrobras

Sapinhoá Field
First Oil
FPSO Cid. São Paulo

Daily record: 581 thousand bopd

CUMULATIVE PRODUCTION
414 million boe

Aug/14

CAMPOS BASIN / RJ
CAMPOS BASIN / ES
SANTOS BASIN

Thousand bopd

0 50 100 150 200 250 300 350 400 450 500 550

aug/08 dec/08 feb/09 apr/09 jun/09 aug/09 dec/09 feb/10 apr/10 jun/10 aug/10 dec/10 feb/11 apr/11 jun/11 aug/11 dec/11 feb/12 apr/12 jun/12 aug/12 dec/12 feb/13 apr/13 jun/13 aug/13 dec/13 feb/14 apr/14 jun/14 aug/14
Production from Pre-Salt Reservoirs Operated by Petrobras

Lula NE Field
First Oil
FPSO Cid. Paraty

Daily record: 581 thousand bopd

CUMULATIVE PRODUCTION
414 million boe

Aug/14

Production from Pre-Salt Reservoirs Operated by Petrobras
Production from Pre-Salt Reservoirs Operated by Petrobras

Production development of Baleia Azul, Baleia Franca and Jubarte fields

P-58

Daily record: 581 thousand bopd

Aug/14 CUMULATIVE PRODUCTION 414 million boe

CUMULATIVE PRODUCTION

Campos Basin / RJ
Campos Basin / ES
Santos Basin

Thousand bopd
Time to Reach a Production of 500,000 bopd

**PETROBRAS**  
Onshore / Shallow Water  
- 1953 to 1984: 31 years  
- 4,108 wells  
- 120 bopd/well

**CAMPOS BASIN**  
Deep Water  
- 1974 to 1995: 21 years  
- 411 wells  
- 1,200 bopd/well

**PRE-SALT**  
Ultra-Deep Water  
- 2006 to 2014: 8 years  
- 25 wells  
- 20,000 bopd/well
Worldwide Comparison

GULF OF MEXICO

NORTH SEA

PRE-SALT

20 YEARS

10 YEARS

8 YEARS
1. Brazilian Pre-Salt

Overview

Main Challenges & Technological Solutions

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Way Forward & Final Message
Libra is Located Close to Búzios Field, in the Pre-Salt Area in Santos Basin

About Libra...

• **Libra area discovered in 2011**

• **Bid for PSC went out in 2013**
  – Consortium formed by Petrobras (40% - operator), Shell (20%), Total (20%), CNOOC (10%) and CNPC (10%)
  – R$15B (~$6.5B) signature bonus
  – 41.65% government share in profit oil

• **PPSA**: manage the PSC, representing the interests of the Brazilian Government
Libra Has an Area of ~1500km$^2$, Equivalent to That of Houston
Libra's Size Has Attracted a Lot of Attention
The Libra Partnership Offers a Vast Array of Opportunities

- Very strong oil companies
- Possibility to share expertise, knowledge and funding
- Collaborative environment
- Integrated project team
- Openness to new ideas
- Multi-cultural partnership
- Resources alignment

PPSA
Local Content is Required in Different Levels

**Examples**

- **Exploration Phase**
  - Production Phase
- **Rigs, hull, subsea tree, drilling equipment**
- **Casing, bits**

**LC requirement**

- **Rigs**: 29%, 50-65%
- **Subsea Tree**: 70%
- **Casing**: 73%
- **Bit**: 5%

**Waiver not applicable**

**Waiver applicable when**:
- Lead time too long
- Higher price
- New technologies
- No local supplier available

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**Local Content**

- Technology development
- Growth of national industry
- Training of local human resource

**Graph**

- Participation of Oil & Gas industry on Brazil's GDP
  - **2000**: 5
  - **2002**: 6
  - **2004**: 7
  - **2006**: 8
  - **2008**: 9
  - **2010**: 12

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Libra's Reservoir Has Very Unique Characteristics

- Very thick pre-salt reservoirs
- Low H₂S
- Good reservoir quality (porosity / permeability)
- High GOR (~440 m³/m³)
- Light Oil ~27 API
- High CO₂ content (~44%)
Base of Salt | Structural Map (c.i. = 100m)

Spill Point: -5700 m
Area above O/W: 578 Km²
Reservoir top: -4750 m
Maximum gross pay: 950 m

2-ANP-2A
Libra1 NW1
Libra2 C1
Libra: Orders of Magnitude

600-900m: estimated reservoir thickness in the central area

Highest Buildings in the World

- Williams Tower (Houston)
- Empire State Building (NYC)
- Sears Tower (Chicago)
- Petronas Towers (Kuala Lumpur)
- Taipei 101 (Taipei)
- Burj Khalifa (Dubai)

Libra Schematic View

- RESERVOIR
- SALT

- 2,000 to 2,500 m
- 1,000 to 1,500 m
- Up to 2,500 m
- Up to 1,000 m
2-ANP-2A-RJS

Gross-pay = 329 m
Net-pay = 277,9 m
N/G = 84,4 %
Øm = 14 %
Sw = 13 %
According to Brazil's National Petroleum Agency (ANP):

8 to 12 Bi bbls recoverable
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Way Forward & Final Message
Libra Project will Leverage Existing Knowledge of the Santos Basin Pre-Salt Area

Santos Basin Pre-Salt Subsurface Information Available at the Beginning of the Field Development

<table>
<thead>
<tr>
<th></th>
<th>2008</th>
<th>Sep 2014</th>
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<tbody>
<tr>
<td><strong>1st Pre-salt mega field development</strong>¹</td>
<td>6</td>
<td>116</td>
</tr>
<tr>
<td>Wells drilled</td>
<td>6</td>
<td>116</td>
</tr>
<tr>
<td>Wells tested</td>
<td>4</td>
<td>57</td>
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<tr>
<td>Wells completed</td>
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<td>36</td>
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<td>EWTs</td>
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<td>9</td>
</tr>
<tr>
<td>Operating Prod. Systems</td>
<td>0</td>
<td>3</td>
</tr>
</tbody>
</table>

1. Development phase initiated in Jan/2008

Source: Petrobras
Libra's First Approach of Full Field Development Considers Pre-Salt Strategy of Phased Development and Partner's Deep Water Expertise

**Phase 0**
- Data acquisition
  - 2014/2020
  - Exploratory / RDA wells
  - EWTs
  - Pilot system

1 pilot project

**Phase 1**
- Operating production > 1MM bbl/d
  - 2021/2030
  - FPSO families adapted to Libra vs...
  - ... systems tailored to different scenarios

First estimate: + 11 Definitive Systems
Exploration / Appraisal Strategy | Preliminary

- **Minimum Exploratory Program:**
  - 3D seismic
  - 2 exploratory wells
  - 1 EWT

- **Full Field Information Acquisition Plan:**
  - Reprocessing of the existing seismic (focus: SE region)
  - New 3D seismic acquisition (OBN is a possibility)
  - Around 30 appraisal wells (2.5 per module)
  - 5 EWTs (1 for each 2 modules)
  - Pilot Production System

- **All wells will be used in the definitive production systems**
EWTs: Reduction of Uncertainty by Understanding Dynamic Behavior is Crucial to Optimize Final Production Systems

1 production and 1 injection well

Production unity with 50K bbl/d of oil capacity and 4MM m³/d of gas compression capacity

EWT with gas reinjection for one year to:
- Test different zones in each well (production / injection perforation and completion strategies)
- Evaluate a large drainage area
- Be able to do more interference tests
- Test high production and injection rates for longer periods
We are Moving Ahead Quickly: First View on Preliminary Libra Full Field Exploration and Development

Minimum Exploratory Program + appraisal wells

L2 in 2022 to allow for EWT to run for at least 6 months and use its information to minimize risk

5 EWTs for each pair of modules, complemented by the information from the pilot

Pilot System to complement information provided by the EWTs
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   Way Forward & Final Message
Characterization challenges:

✓ Inversion and 4D studies
✓ Heterogeneities understanding and incorporation in the 3D geologic model
✓ Better understanding of the coquinas, mainly regarding sweep efficiency

Challenges due to fluids characteristics:

✓ High GOR
✓ High CO₂ content
✓ High temperature
✓ Possible compositional grading (GOR, CO₂, H₂S)
✓ Near critical behavior

Challenges due to reservoir thickness:

✓ Inject gas at the top and water at the base?
✓ Inject and produce throughout the whole oil column?
✓ Exclusive wells for the microbial and for the coquinas reservoirs?
✓ What are the impacts of producing up to 50 kobpd in one single well?
Challenges due to gas management:

✓ Full reinjection or treatment + export?
✓ Is it worthy to perform WAG?
✓ Reinjection impacts: miscibility? Fingering? Asphaltenes?

WAG:

✓ Motivation: high CO\textsubscript{2} content and commitment not to flare it
✓ Advantages: improve sweep and displacement efficiency and provide flexibility for reservoir management
✓ Lab and numerical studies: miscibility, characterization of the multiphase flow in reservoir conditions, gravity effects, estimate of the incremental RF, injectivity behavior
Potential increase diameters of production string (extremely high production / injection rates)

Smart completion in 2, 3 or more zones (multiplex?)

Downhole chemical injection, with selectivity

Contaminants content require special metallurgy (SDSS), but there is a high local content requirement as well (new materials?)

Improvement of drilling performance (e.g. salt drilling, carbonate drilling)

Use MPD system in large scale, minimizing impacts in the durations and maintaining the highest HSE standards
• Rigs specialization scenarios (LWO, SESV, etc)
• Factory drilling concept (logistics, execution)
• Dry completion semisub / Direct Vertical Access (DVA semi)
Flow Assurance

- **Asphaltenes**
  - Higher risks due to gas reinjection
  - It may be necessary to keep pwf above a limit pressure
  - Continuous downhole injection of inhibitor

- **Scaling**
  - CaCO$_3$ and sulfates deposition risks
  - Mitigation: injection of desulfated water, continuous scaling inhibitor injection, remote squeeze

- **Hydrates**
  - Higher risks in case of WAG application
  - Mitigation: thermal insulation / specific operational procedures

- **Wax**
  - Mitigation: risers and flowlines thermal insulation
  - Pressure and GOR management – minimize deposition in the risers
  - Frequent pigging may be needed
- Potential increase in risers and flowlines diameters (higher flow rates, manifolds)
- New concepts for risers systems
- Use of gathering ring + inline Ts solution
- Use of 2 PLSV’s (Pipe line supply vessel) or pre-installation
- Subsea boosting/reinjection systems
- Subsea gas-liquid separation + gas hub or dense phase reinjection (Hi-Sep)
- WAG: separated lines for gas and water injection and operational issues – hydrates, multiple control systems
Surface Facilities

- Maximum oil processing capacity depends basically on:
  - GOR (for Libra: GOR ~ 450 sm³/m³)
  - CO₂ content (for Libra: CO₂ in gas phase ~ 45%)
  - Requirement for contaminants removal (CO₂, H₂S?)
  - Water injection rate required to maintain reservoir pressure – increases with Bo (for Libra: Bo ~ 2)

- Main constraints for topsides capacities:
  - Total weight
  - Deck area required for the modules installation
  - Power demand
  - Gas treatment & compression
Gas export schemes (FLNG, pipelines, GTW)

Maximum capacities could be limited if there is a decision / requirement to treat and export the gas

New technologies for CO$_2$ removal, gas dehydration and H$_2$S removal

Materials selection / development

Construction of the hulls (new built or converted) and all modules in Brazil

Process plant reliability

Higher capacity plants would add a significant value to the overall project
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After ~ 40 Production Systems Come into Stream in Brazil
Until 2020, Local Supplier Capacity Will Turn to Libra

Petrobras Oil and NGL production curve in Brazil

From 2020 to 2030...
... the domestic supplier capacity developed for the Pre-salt projects will heavily support Libra

The Libra decade

2013
- Sapinhoá Pilot
- Lula NE Pilot
- Baúna
- Papa-Terra (P63)
- Roncador

2014
- Sapinhoá Norte
- Iracema Sul
- Norte Pq Baleias
- Roncador IV
- Papa-Terra (P61)
- Papa-Terra (TAD)

2015
- Iracema Norte
- Lula Alto
- Lula Central
- Lula Sul
- Lula Norte
- Búzios I
- Lapa

2016
- Lula Alto
- Lula Central
- Lula Sul
- Lula Norte
- Búzios I
- Lapa

2017
- Lula Ext. Sul e ToR Sul de Lula
- Lula Oeste
- Iara Horst
- Búzios III
- Búzios IV
- Tartarga Verde and Mestiça

2018
- NE de Tupi
- Iara NW
- Carcará
- Ent. Iara
- Deep Water ES
- Marlim I Revitalization
- Deep Water I SE
- Sul Pq das Baleias
- Maromba I

2019
- Jupiter
- Búzios V

2020
- Florim
- Espadarte III
- Deep Water II SE
- Marlim II Revitalization
- Libra

New Discoveries
- Onerous Assignment
- Pre-salt Concession
- Other Areas
The Way Forward to 2020 | Petrobras Oil Production

Multiplex completions

- 1.93 million bopd
- +7.5%
- +1%

- 52% Post-Salt
- 53% Pre-Salt

The Way Forward to 2020 | Petrobras Oil Production

Ocean bottom sensors for seismic imaging

- Pre-Salt: 7%
- Post-Salt: ~20%
- Pre-Salt: 52%
- Post-Salt: 53%

2013: 1.93 million bopd
2014: +7.5%
2015: ~1%
2016: 3.2 million bopd
2017:
2018:
2019:
2020: 4.2 million bopd
The Way Forward to 2020 | Petrobras Oil Production

Advanced membrane materials for CO₂ separation from natural gas

- 2013: 1.93 million bopd
- 2014: +7.5%
- 2015: +- 1%
- 2016: 3.2 million bopd
- 2017:
- 2018: 4.2 million bopd
- 2019:
- 2020:

Pie charts showing the distribution of oil production:
- Post-Salt:
  - 2013: 7%
  - 2014: ~20%
  - 2015:
  - 2016:
  - 2017:
  - 2018:
  - 2019:
  - 2020: 52%
- Pre-Salt:
  - 2013:
  - 2014:
  - 2015:
  - 2016:
  - 2017:
  - 2018:
  - 2019:
  - 2020: 53%
The Way Forward to 2020 | Petrobras Oil Production

4.2 million bopd

Petrobras Production in Brazil

Subsea processing: Subsea Separation and Pumping

BMSHA

SSGL

2020-2030
The Way Forward to 2020 | Petrobras Oil Production

4.2 million bopd

Petrobras Production in Brazil

Nanotechnology applied for increasing reservoir recovery and materials
4.2 million bopd

Petrobras Production in Brazil

2020-2030

Laser drilling
The Way Forward to 2020 | Petrobras Oil Production

Petrobras Production in Brazil

4.2 million bopd

Large Capacity FPUs

2020-2030

2020

2030
Technological Park in Rio de Janeiro

Technological Centers Installed

TECHNOLOGICAL CENTERS INSTALLED

TO BE INSTALLED

BG GROUP
Libra will become a supergiant field, with several opportunities and challenges for the next years (and decades):

- Paradigms will be revised
- Technological boundaries will be expanded
- A pioneer contract and partnership model in Brazil will be developed, serving as a pilot for all the future Pre-Salt blocks
THANK YOU

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