Frontier Exploration in Sub Andean Zone of Peru*

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Abstract

The exploration in the Sub Andean basins of Peru has a long history with many important discoveries. The creaming curve and field size distribution of the foreland basins show that they have reached a plateau and unless changes are made to exploration play ideas, discoveries will be minimum and small. An exploration case study is presented in the thrust fold belt area of Peru in the Ene and Madre de Dios basins showing how all the elements and the processes of the petroleum systems have been assessed, looking for new exploration plays, understanding the risk, and estimating the reward in case of success.

Selected Reference

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Juan Chung / Pierre Callot
Pluspetrol Peru Corporation

Session IV: Future Exploration Potential in Bolivia and Beyond
Outline

✓ Introduction
✓ Exploration in the Peruvian Sub Andean Basins
✓ Frontier Exploration in Ene Basin
✓ Conclusions
**INTRODUCTION**

Sub Andean Basins of Peru

- Foreland Basin System
  - Wedge Top
  - Fore Deep
  - Fore Bulge
  - Back Bulge

- Sub Andean Basins of Peru
  - Marañon
  - Ucayali
  - Madre de Dios
  - Santiago
  - Bagua
  - Huallaga
  - Pachitea
  - Ene
INTRODUCTION
Sub Andean Basins of Peru

✓ Foreland Basin System
  • Wedge Top
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  • Marañón
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  • Madre de Dios
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  • Bagua
  • Huallaga
  • Pachitea
  • Ene

Peter G. DeCelles, 1996
INTRODUCTION

Sub Andean Basins of Peru

Foreland Basin System
- Wedge Top
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Sub Andean Basins of Peru
- Marañón
- Ucayali
- Madre de Dios
- Santiago
- Bagua
- Huallaga
- Pachitea
- Ene

Peter G. DeCelles, 1996
INTRODUCTION

Structural Styles

Marañon
Ucayali
Madre de Dios
Bagua

1. Structural Cross Section of Santiago to Maraño Basin
   Perupetro 2003

2. Eastern Cordillera
   Biabo Anticline
   Tarapoto Thrust Sheet
   Perupetro 2003

3. Structural Cross Section
   Pluspetrol 2012

4. Structural Cross Section
   Pluspetrol 2014

5. Structural Cross Section
   Pluspetrol 2012
INTRODUCTION

Main Source and Reservoir Rocks

Modified from Humberto Eduardo 2013 & Pluspetrol 2017
## EXPLORATION IN THE SUBANDEAN BASINS

### Exploratory Discoveries in Peru 2005-2017

<table>
<thead>
<tr>
<th>#</th>
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<td>20</td>
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<td>Ucayali</td>
<td>Los Angeles</td>
<td>Light oil</td>
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EXPLORATION IN THE SUBANDEAN BASINS

Marañon Basin

- Area: 212,428 km²
- 2D Seismic Lines: ~49,000 km
- Exploratory Wells drilled: 113 wells in over 45 years
- Field Discovered: 29 (2P: ~ 2,000 MMBOE)
EXPLORATION IN THE SUBANDEAN BASINS
Ucayali Basin

- **Area**: ~100,000 km²
- **2D Seismic Coverage**: ~20,000 km
- **Exploratory Wells Drilled**: 40 wells in over 60 years
- **Field Discovered**: 9 (2P: 150 MMBOE)

Huge anticlines related to high angle fault inversion with basement involved. Only small fields discovered.
EXPLORATION IN THE SUBANDEAN BASINS
Camisea – Madre de Dios

Number of Exp. Wells by Year

Field Size Distribution

- Area: ~137,000km²
- Seismic coverage: 2D: ~14,800 km; 3D: 2500km
- 28 Exploratory Wells Drilled
  - Foreland: 8 Wells
  - TFB: 20 (12 Fields Discovered)
- 2P Reserve Discovered: 4,500 MMBOE
EXPLORATION IN THE SUBANDEAN BASINS

Northern and Central Thrust Fold Belt in Peru are under-explored.

- **Santiago Basin**
  - 8 wells drilled (Mobil 1968, 3; Quintana 1997/8, 4; Pacific 2016, 1)
  - 1,700 Km of 2D Seismic Line

- **Huallaga Basin**
  - 1 well drilled by Mobil (1992)
  - 1,340 Km of 2D Seismic Line

- **Bagua Basin**
  - No Wells / No Seismic

- **Ene Basin**
  - No wells drilled
  - 740 Km of 2D Seismic Line
Southern Thrust Fold Belt in Peru is a proven and prolific play.

- **Camisea – Madre de Dios**
  - 20 Exploratory Wells drilled
  - 12 Fields discovered
  - 2P Reserves of 4500 MMBOE
- Basin Under-explored
- No wells in the Basin
- Nearest Fields:
  - Camisea (18 TCF; 1,000 MMBNGL)
  - Los Angeles (30 MMBO)
  - Agua Caliente (EUR: 19 MMBO)
  - Aguaytia (388 BCF)
- Big area with few seismic
  - ELF (1996) 230 km
  - Pluspetrol (2015) 524 km
Located in the fold and thrust belt area of the Peruvian Central Andes.

Major tectonic blocks interact controlling the structural deformation.

More than 6000m of sediments from Devonian to Early Tertiary in depocenter.

Two main Stratigraphic provinces are defined a “Rift domain and a foreland similar to Camisea area.

The main structures have a NW-SE orientation, and they are related to big thrust faults and rift inversion zones.
Basin evolution of the area shows two major stratigraphic provinces: Syn Rift stratigraphic province in the West and foreland stratigraphic province in the East. During Andean tectonic orogeny, a rift tectonic inversion developed in the west and the shortening transferred to the foreland basin producing thin...

FRONTIER EXPLORATION IN ENE BASIN

Basin Evolution
Northern Zone:
- Inversion of Tr-Jr Rift faults, salt domes, and thin-skinned structures detached in the pre-Permian salt layer can be considered as potential structural traps for hydrocarbons.
- Jurassic Pucará Gr. represents a potential oil source rock in this area. Paleozoic rock maturity suggests a gas prone source rock.
- Cretaceous & Pre-Cretaceous reservoirs are very well developed in this area.

Southern Zone:
- Boca Satipo Play extends southward of the BSSTE prospect.
- Big syncline and a wider area suggest the presence of bigger structures.
Tertiary Cycle:
• Fine clastic sediments “Red Beds”.
• Thickness variation due to erosion.
• Major seal rock.

Cretaceous Cycle:
• Clastic & carbonate (Aptian to Maastrichtian).
• Reservoirs: Vivian Fm., Oriente Group
• Seal: Chonta Shale.

Upper Paleozoic – Lower Cretaceous:
• Clastic units Barremian in age and older were identified below the Oriente Group.
• Pucara Group is present in the eastern cordillera and Pachitea Sub-Basin. Aeolian facies of this cycle could be an important reservoir.

Paleozoic Cycle:
• Clastic & carbonate units (Ordovician to Permian).
• Giant unconformity controls the distribution of Pz.
• This cycle includes the Carboniferous - Devonian source rocks and the Permian reservoir of Camisea area.
**FRONTIER EXPLORATION IN ENE BASIN**

*Exploration Plays Concept*

<table>
<thead>
<tr>
<th>Structural Style</th>
<th>Rift Inversion</th>
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<tbody>
<tr>
<td>Primary Source Rock</td>
<td>Jr - Pucara (Aramachay Mb)</td>
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<tr>
<td>Secondary Source Rock</td>
<td>Paleozoic (Ene/Ambo/Cabanillas)</td>
</tr>
<tr>
<td></td>
<td>LwKr- Chaypaya</td>
</tr>
<tr>
<td>Primary Reservoir</td>
<td>Kr (Vivian, Oriente Gp.)</td>
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<tr>
<td></td>
<td>Pre-Kr Sst</td>
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<tr>
<td>Secondary Reservoirs</td>
<td>Permian Sst (Ene / Noi)</td>
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<table>
<thead>
<tr>
<th>Structural Style</th>
<th>Thin Skin</th>
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<tbody>
<tr>
<td>Primary Source Rock</td>
<td>Paleozoic (Ambo Gp./Cabanillas)</td>
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<tr>
<td>Secondary Source Rock</td>
<td>Paleozoic (Ene Fm.)</td>
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<td>Primary Reservoir</td>
<td>Kr (Vivian, Oriente Gp.)</td>
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<td>Secondary Reservoirs</td>
<td>Permian Sst (Ene / Noi)</td>
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</table>
FRONTIER EXPLORATION IN ENE BASIN
Seismic Interpretation

Play Type 1

Play Type 2

2 km

Top K

Base K

SW

NE
11) Well Oxapampa 7-1
- Chonta Fm outcropping
- Gas Chromatography +C4
- Res: Cushabatay Fm (134m)

10) Fluid Inclusions
@ Cushabatay, Tmax 115-130°C

9) Oil Impregnation in Boca Satipo fault
Origin: Ambo.

8) Fluid Inclusions
@ Ene, 34-36°API

7) Fluid Inclusions
@ Ene, >52°API

6) Fluid Inclusions
@ Ene, 12-15°API

5) Fluid Inclusions
@ Ene, >52°API

4) Fluid Inclusions
@ Ene, 34-36°API

3) Gas Seep
Oxapampa 19-1
Well Head

2) Outcrop Sample
Ene Fm SST with oil, fluorescence bright yellow and cut.

1) Oil Stain
CEL-04
FRONTIER EXPLORATION IN ENE BASIN
Reservoirs Quality

Cretaceous Reservoirs
Mean = 13.0%

Paleozoic Reservoirs
φ mean = 14%
Peruvian Subandean Basins

- Northern Foreland Basin (Marañón): Well Explored and Successful, Required change in exploration ideas for bigger discoveries.

- Southern/Central Foreland Basins: Under-explored (specially Madre de Dios basin), small historic discoveries in the Ucayali basin. Stratigraphic trap is a promising exploration play in Madre de Dios.


- Southern Ene Basin could be the continuation of the play Camisea-MDD, by the end of this year an exploratory well will be drilled.