

Frontier Exploration in Sub Andean Zone of Peru*

Juan Chung¹ and Pierre Callot¹

Search and Discovery Article #11160 (2018)**

Posted December 10, 2018

*Adapted from oral presentation given at AAPG Latin America & Caribbean Region, Optimizing Exploration and Development in Thrust Belts and Foreland Basins, Santa Cruz de la Sierra, Bolivia, June 6-8, 2018

**Datapages © 2018 Serial rights given by author. For all other rights contact author directly. DOI:10.1306/11160Chung2018

¹Pluspetrol Peru Corporation, Lima, Peru (jchung@pluspetrol.net)

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

DeCelles, P.G., and K.A. Giles, 1996, Foreland Basin Systems: Basin Research, v. 8, p. 105-123.



Frontier Exploration In Sub Andean Zone of Peru

Juan Chung / Pierre Callot
Pluspetrol Peru Corporation

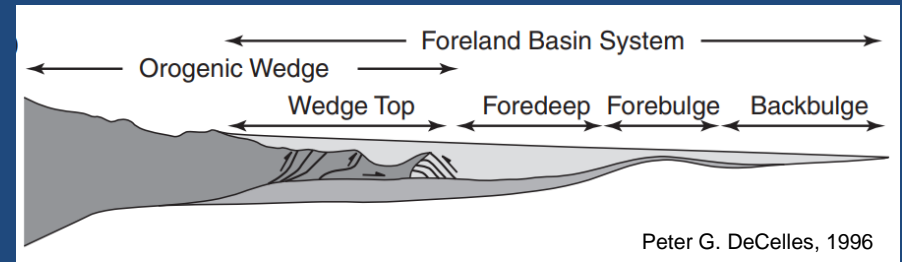
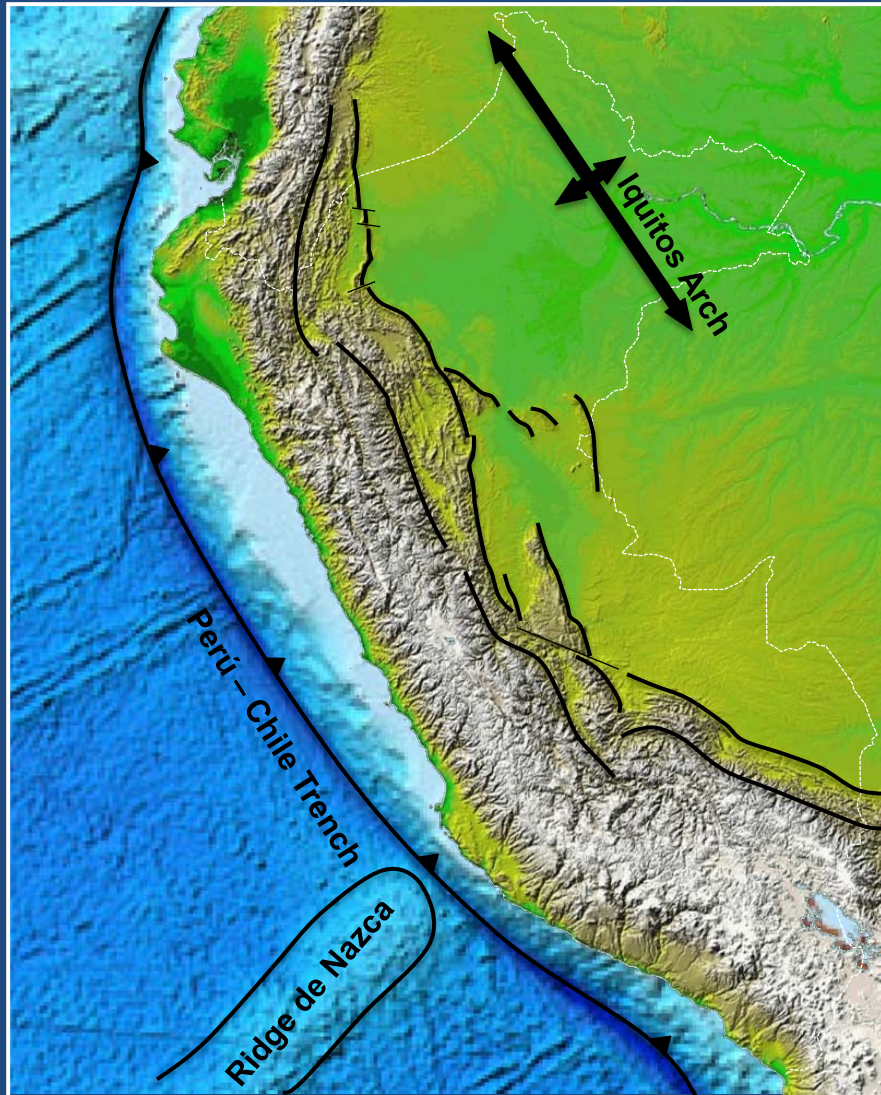
Session IV : Future Exploration Potential in Bolivia and Beyond

Outline

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

INTRODUCTION

Sub Andean Basins of Peru



✓ Foreland Basin System

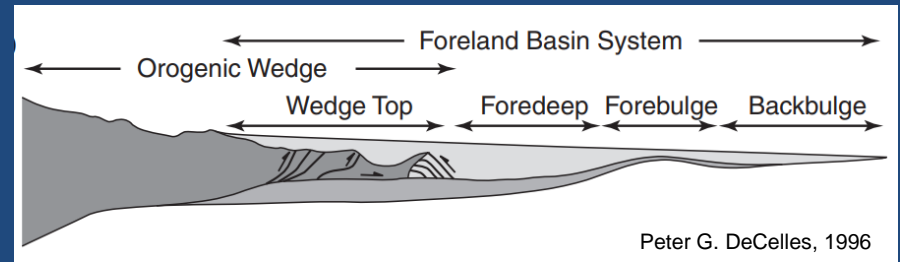
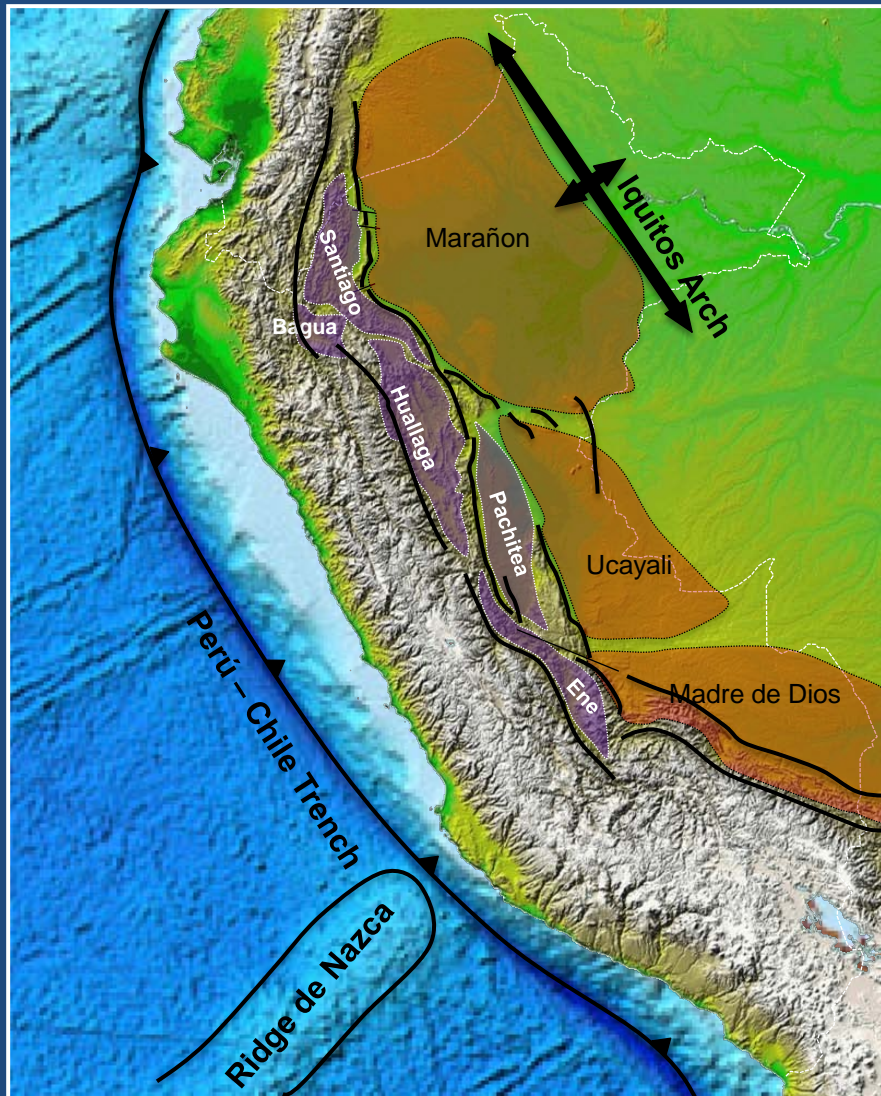
- Wedge Top
- Fore Deep
- Fore Bulge
- Back Bulge

✓ Sub Andean Basins of Peru

- Marañon
- Ucayali
- Madre de Dios
- Santiago
- Bagua
- Huallaga
- Pachitea
- Ene

INTRODUCTION

Sub Andean Basins of Peru



✓ Foreland Basin System

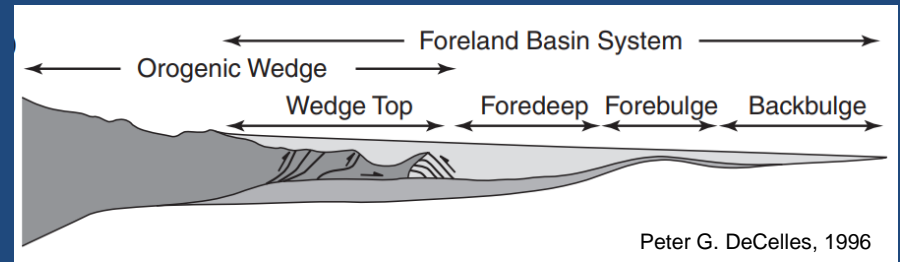
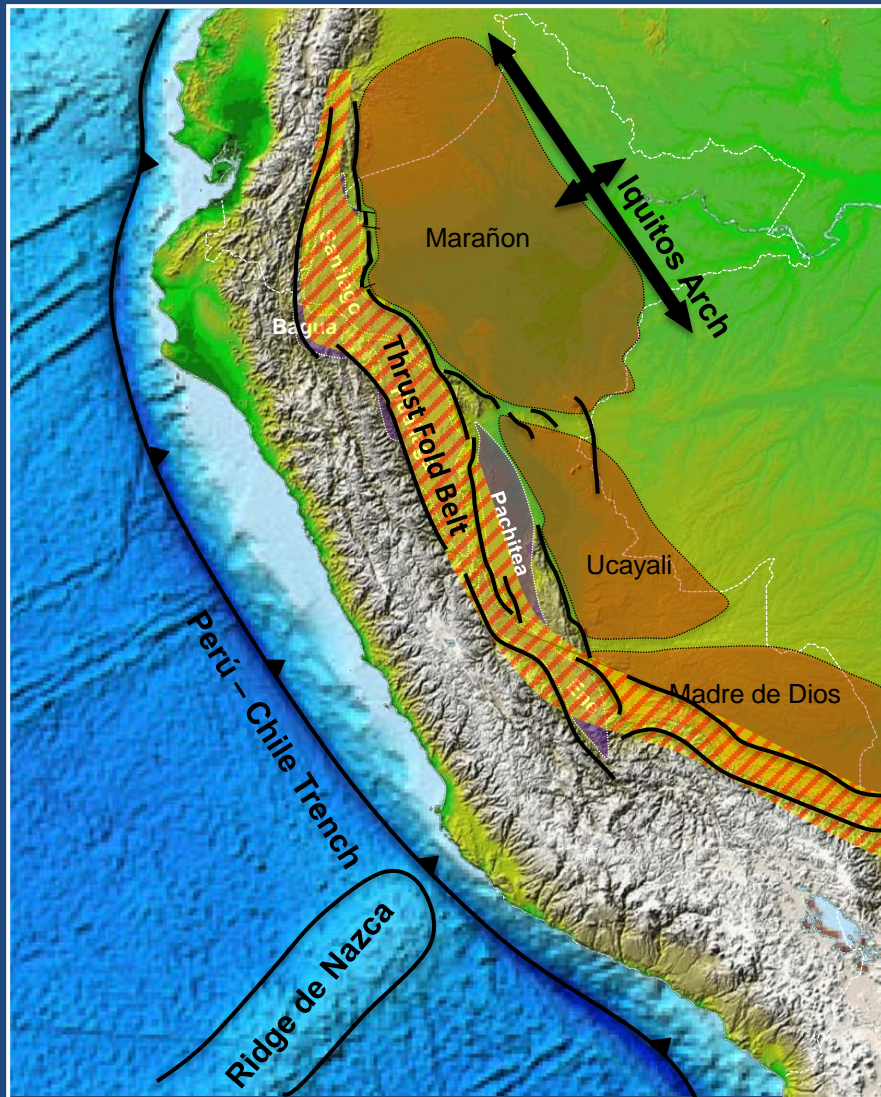
- Wedge Top
- Fore Deep
- Fore Bulge
- Back Bulge

✓ Sub Andean Basins of Peru

- Marañon
- Ucayali
- Madre de Dios
- Santiago
- Bagua
- Huallaga
- Pachitea
- Ene

INTRODUCTION

Sub Andean Basins of Peru



✓ Foreland Basin System

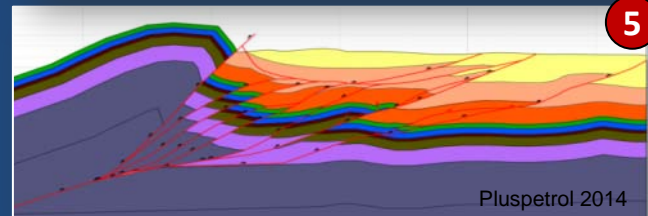
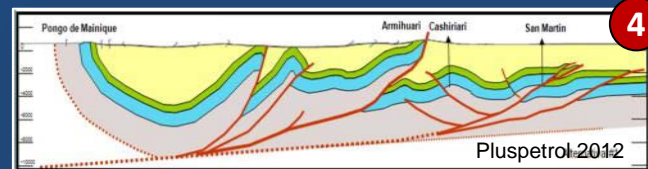
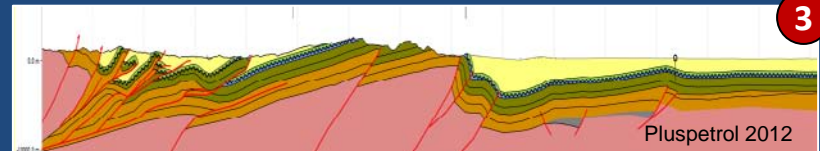
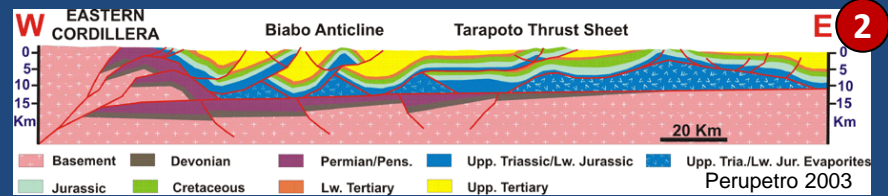
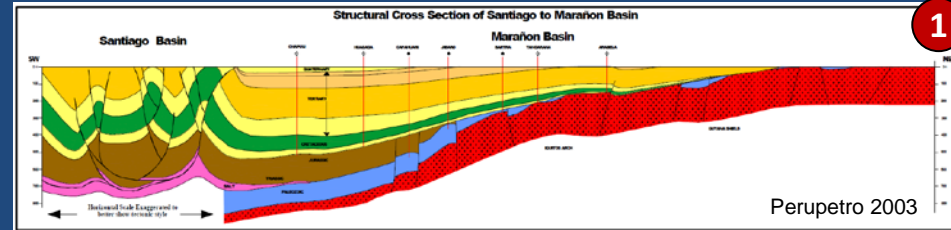
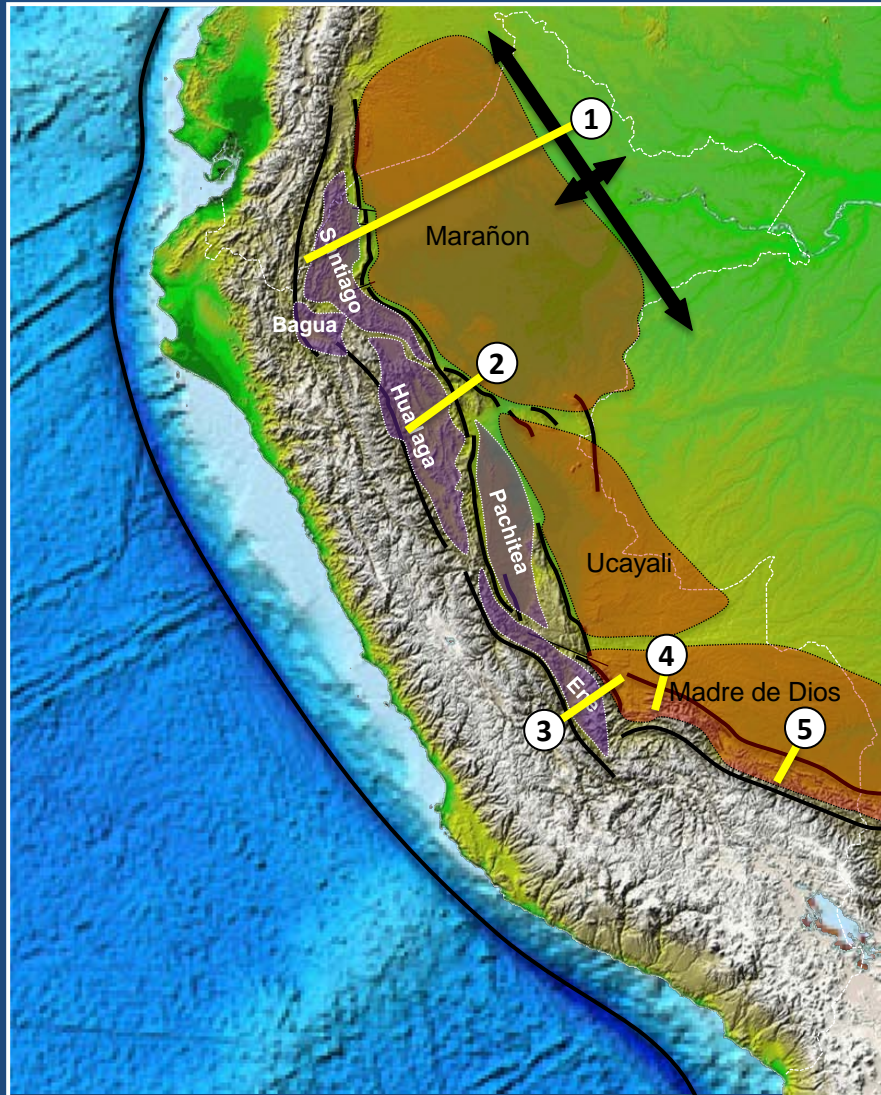
- Wedge Top
- Fore Deep
- Fore Bulge
- Back Bulge

✓ Sub Andean Basins of Peru

- Marañón
- Uçayali
- Madre de Dios
- Santiago
- Bagua
- Huallaga
- Pachitea
- Ene

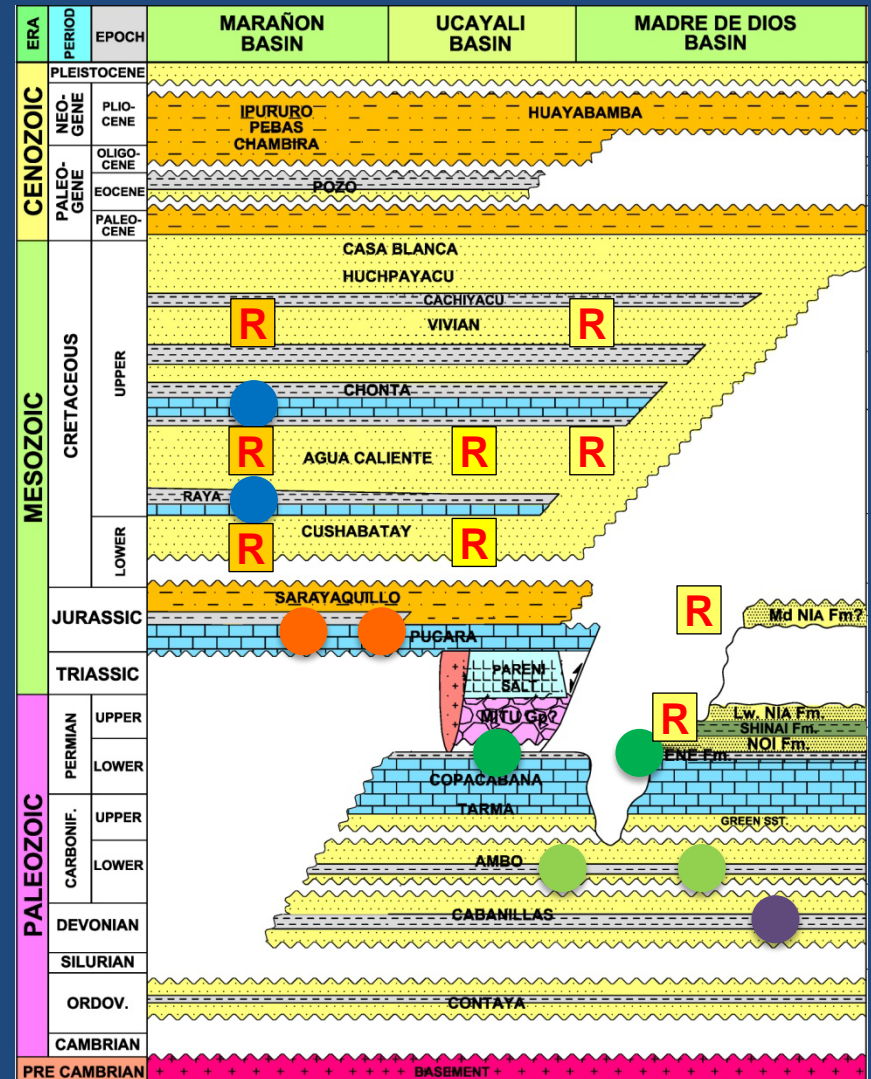
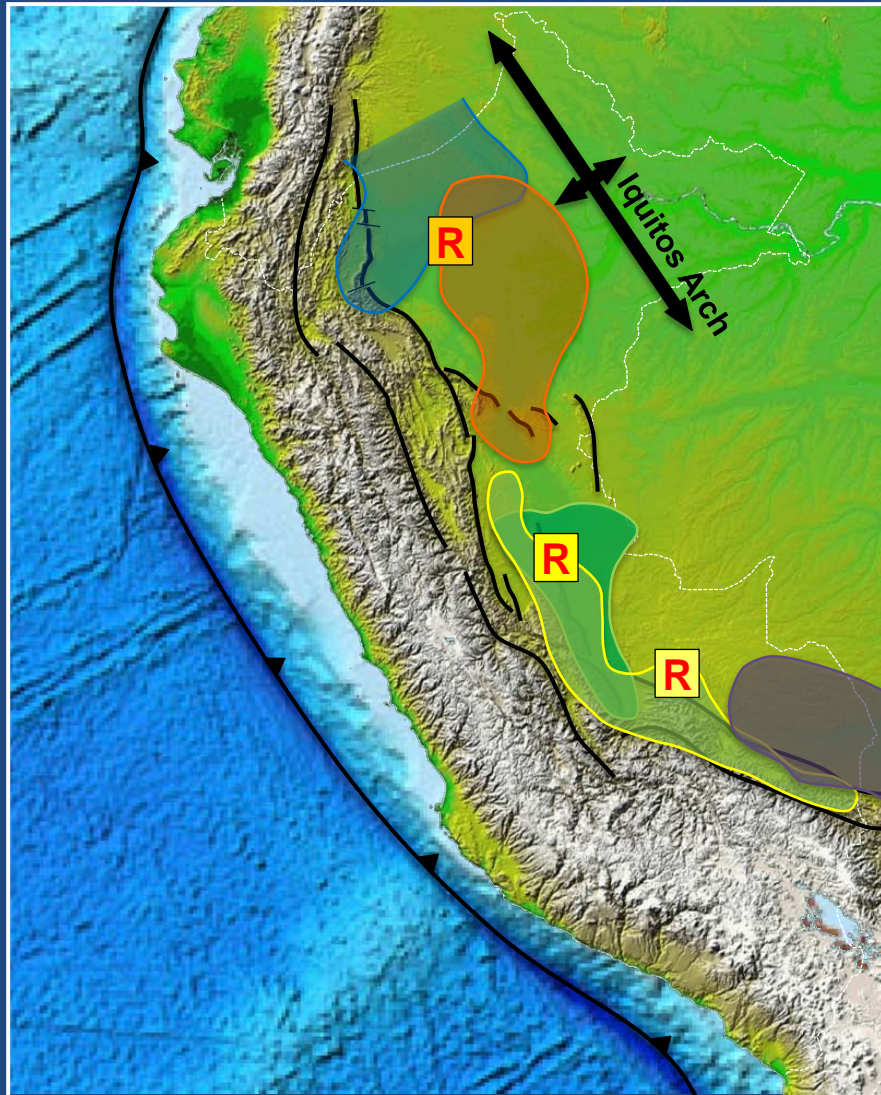
INTRODUCTION

Structural Styles



INTRODUCTION

Main Source and Reservoir Rocks



Modified from Humberto Eduardo 2013 & Pluspetrol 2017

EXPLORATION IN THE SUBANDEAN BASINS

Exploratory Discoveries in Peru 2005-2017

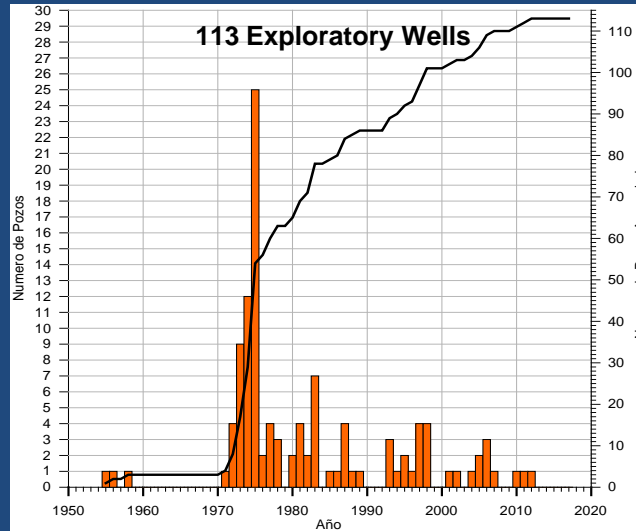
#	Discovery Year	Basin	Field	Type
1	2005	Marañon	Situche C. 2X	Ligth oil
2	2005	Offshore Talara	San Pedro 1X	Ligth oil
3	2005	Marañon	Buenavista	Heavy oil
4	2006	Marañon	Raya 3X	Heavy oil
5	2006	Marañon	Delfin 2X	Heavy oil
6	2007	Talara	La Isla	Ligth oil
7	2007	Marañon	Carmen Noreste	Mid Oil
8	2007	Camisea - MDD	Kinteroni	Gas & Cond.
9	2007	Offshore Talara	San Pedro Este	Gas
10	2008	Offshore Talara	Esperanza	Ligth oil
11	2008	Offshore Talara	San Francisco	Gas
12	2008	Camisea - MDD	Urubamba	Gas & Cond.
13	2010	Camisea - MDD	Picha	Gas & Cond.
14	2011	Camisea - MDD	Taini	Gas & Cond.
15	2011	Camisea - MDD	Mipaya	Gas & Cond.
16	2012	Marañon	Boa	Oil (21°API)
17	2012	Ucayali	Sheshea	Ligth oil
18	2013	Marañon	Bretaña Norte	Oil (18°API)
19	2013	Camisea - MDD	San Martin Este	Gas & Cond.
20	2013	Ucayali	Los Angeles	Ligth oil

EXPLORATION IN THE SUBANDEAN BASINS

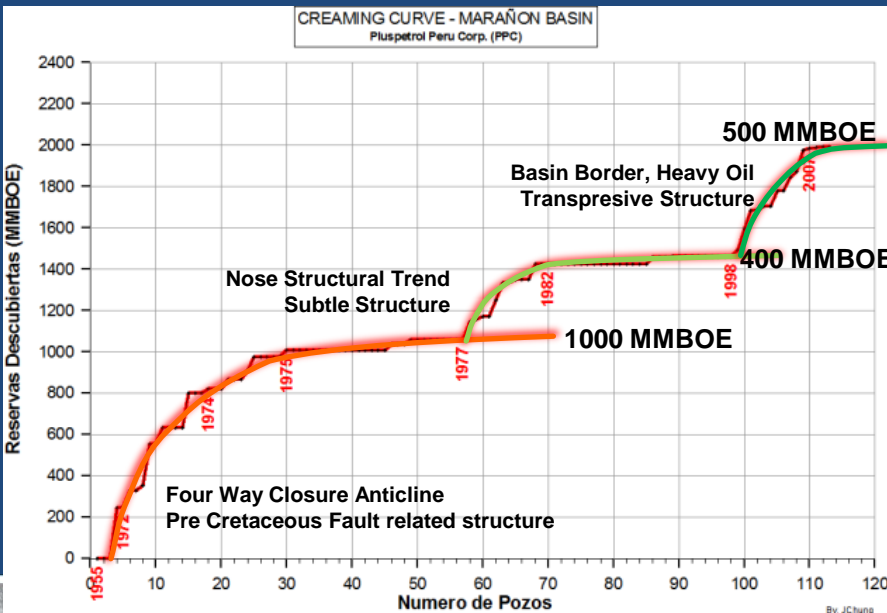
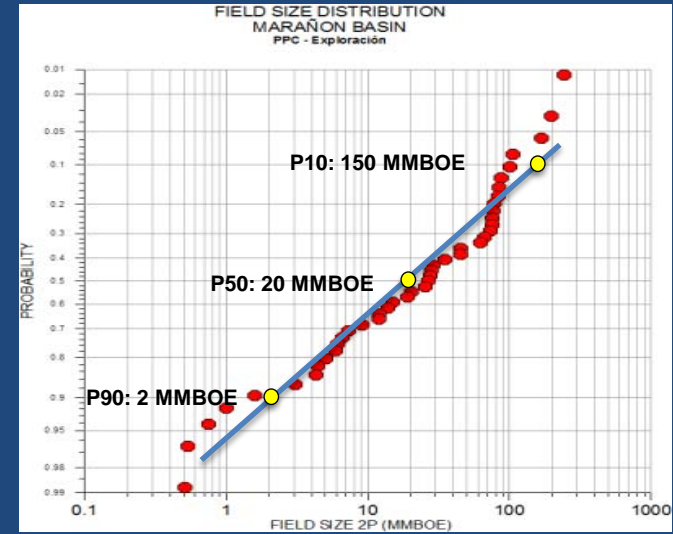
Marañon Basin



Number of Exp. Wells by Year



Field Size Distribution



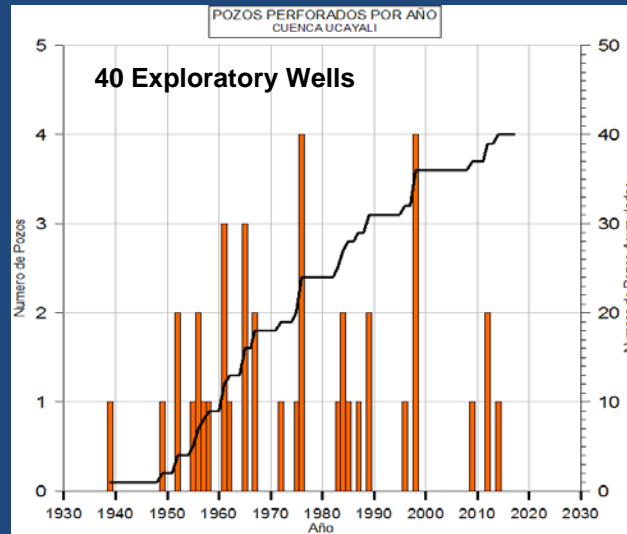
- ✓ Area: 212,428 km²
- ✓ 2D Seismic Lines: ~49,000 km
- ✓ Exploratory Wells drilled: 113 wells in over 45 years
- ✓ Field Discovered: 29 (2P: ~ 2,000 MMBOE)

EXPLORATION IN THE SUBANDEAN BASINS

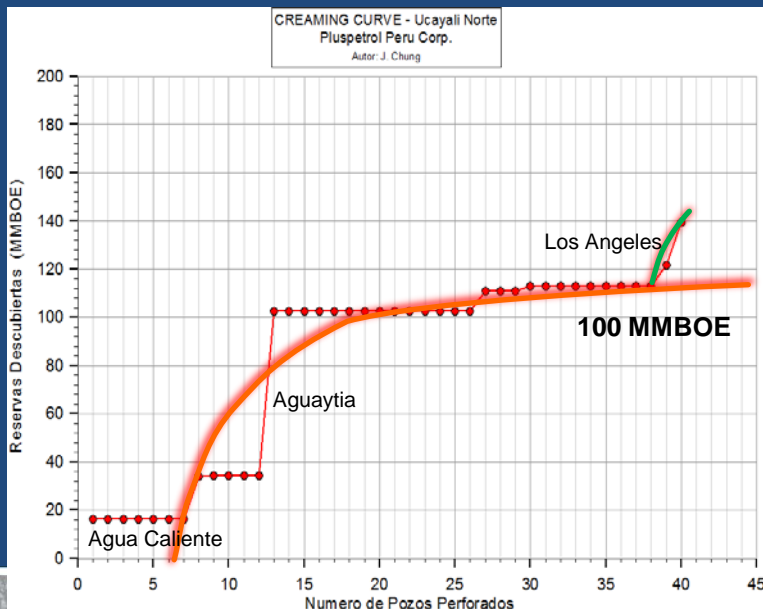
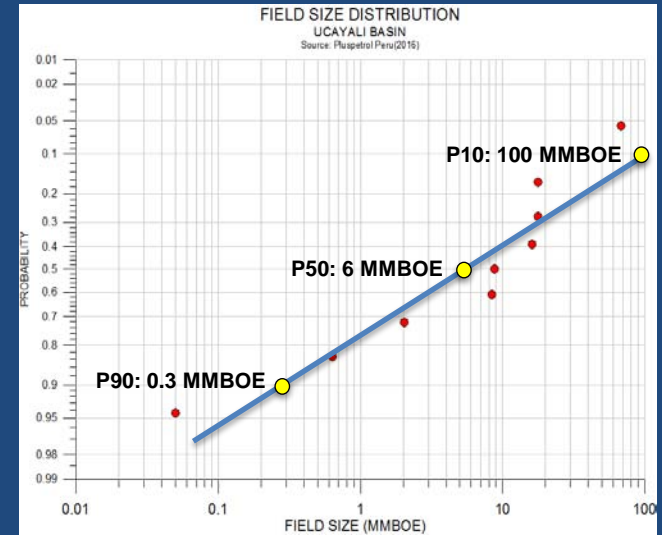
Ucayali Basin



Number of Exp. Wells by Year



Field Size Distribution

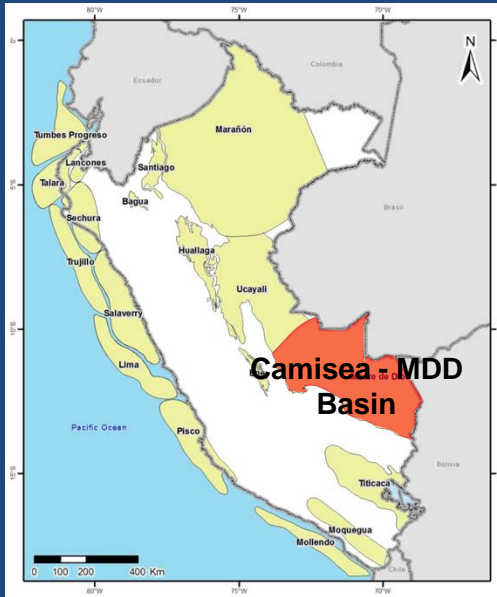


- ✓ Area: ~100,000 km²
- ✓ 2D Seismic Coverage: ~20,000 km
- ✓ Exploratory Wells Drilled: 40 wells in over 60 years
- ✓ Field Discovered: 9 (2P: 150 MMBOE)

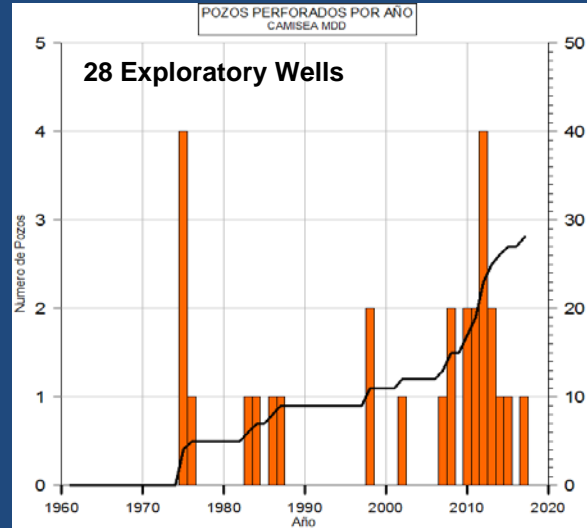
Huge anticlines related to high angle fault inversion with basement involved. Only small fields discovered.

EXPLORATION IN THE SUBANDEAN BASINS

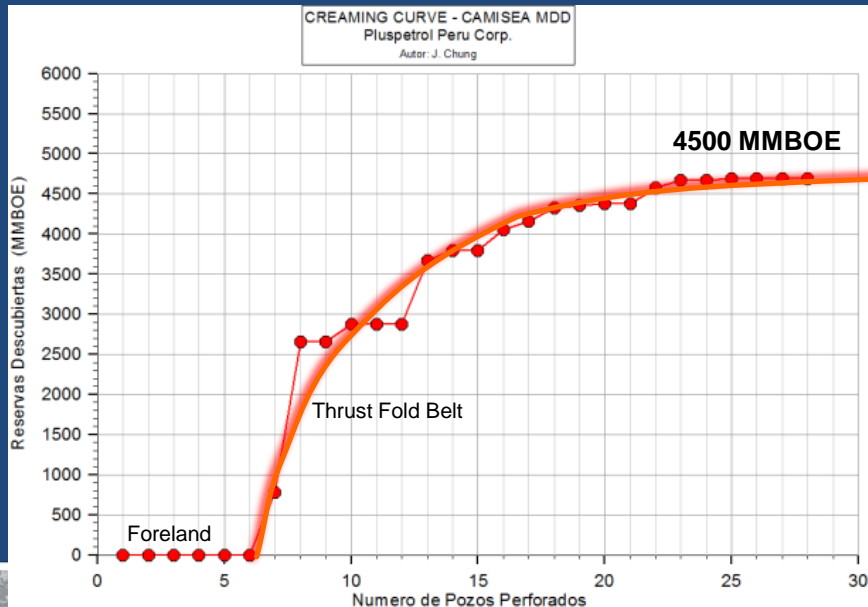
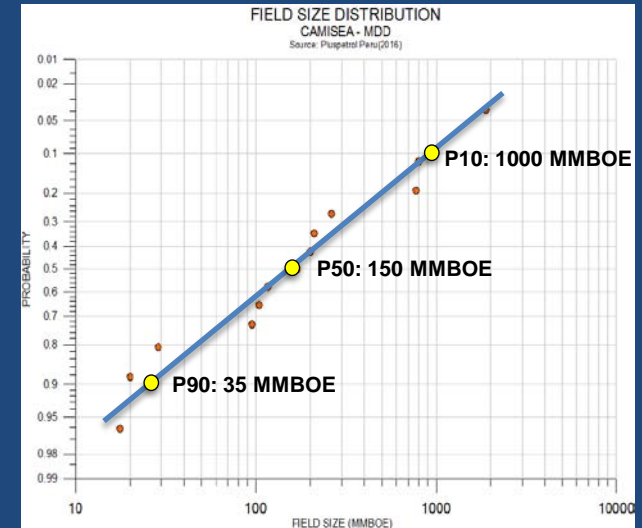
Camisea – Madre de Dios



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

Northern and Central Thrust Fold Belt in Peru are underexplored.

✓ Santiago Basin

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

✓ Hualлага Basin

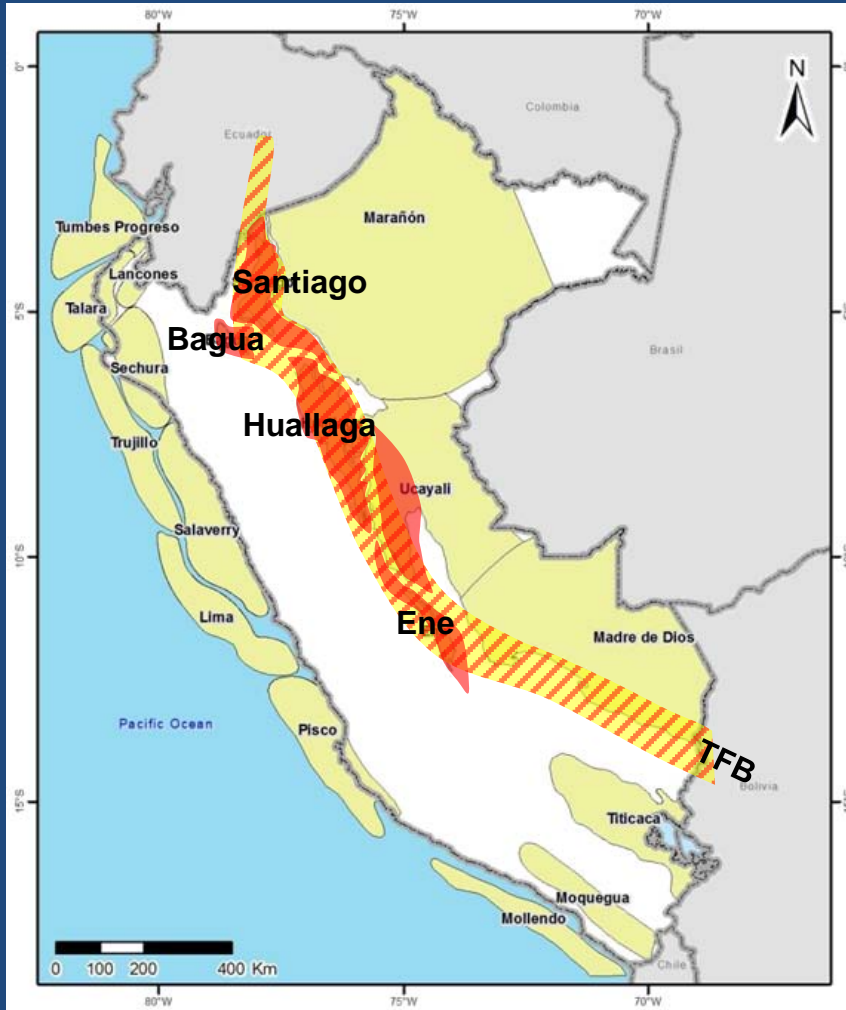
- 1 well drilled by Mobil (1992)
- 1,340 Km of 2D Seismic Line

✓ Bagua Basin

- No Wells / No Seismic

✓ Ene Basin

- No wells drilled
- 740 Km of 2D Seismic Line



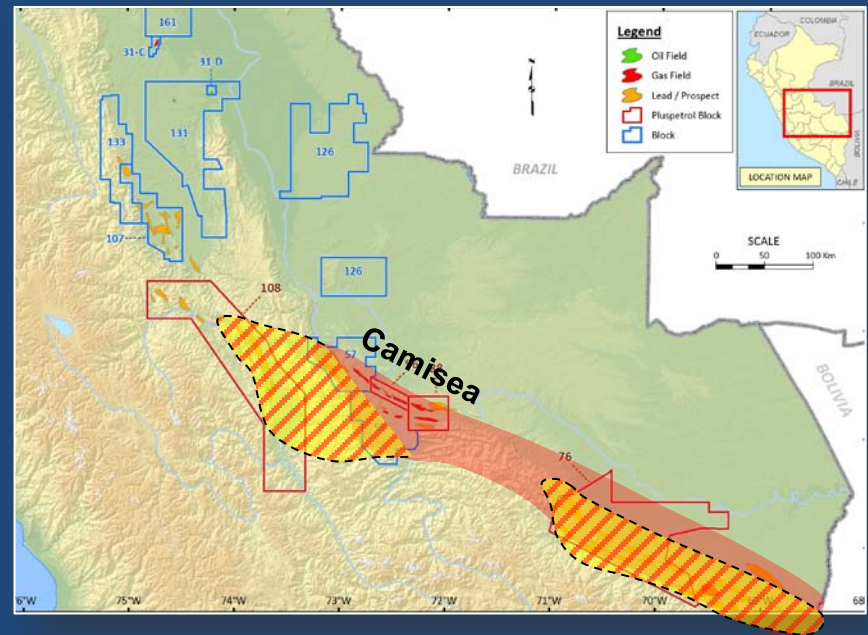
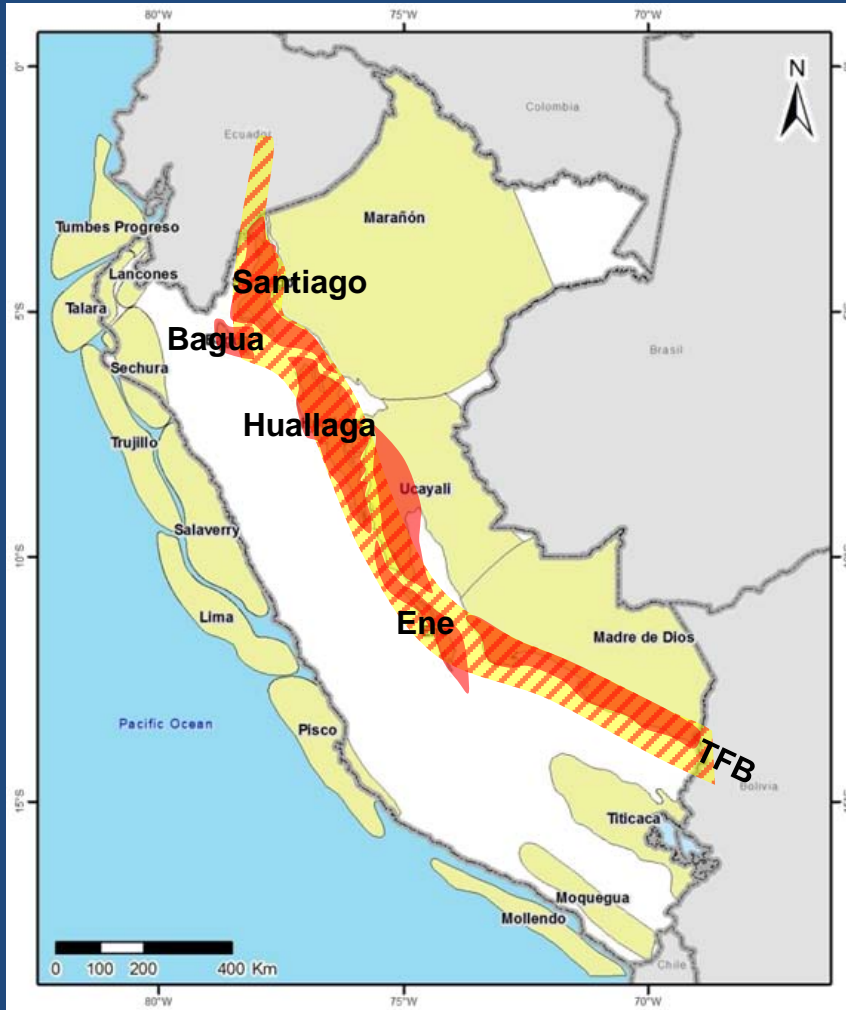
EXPLORATION IN THE SUBANDEAN BASINS

Southern Thrust Fold Belt

Southern Thrust Fold Belt in Peru is a proven and prolific play.

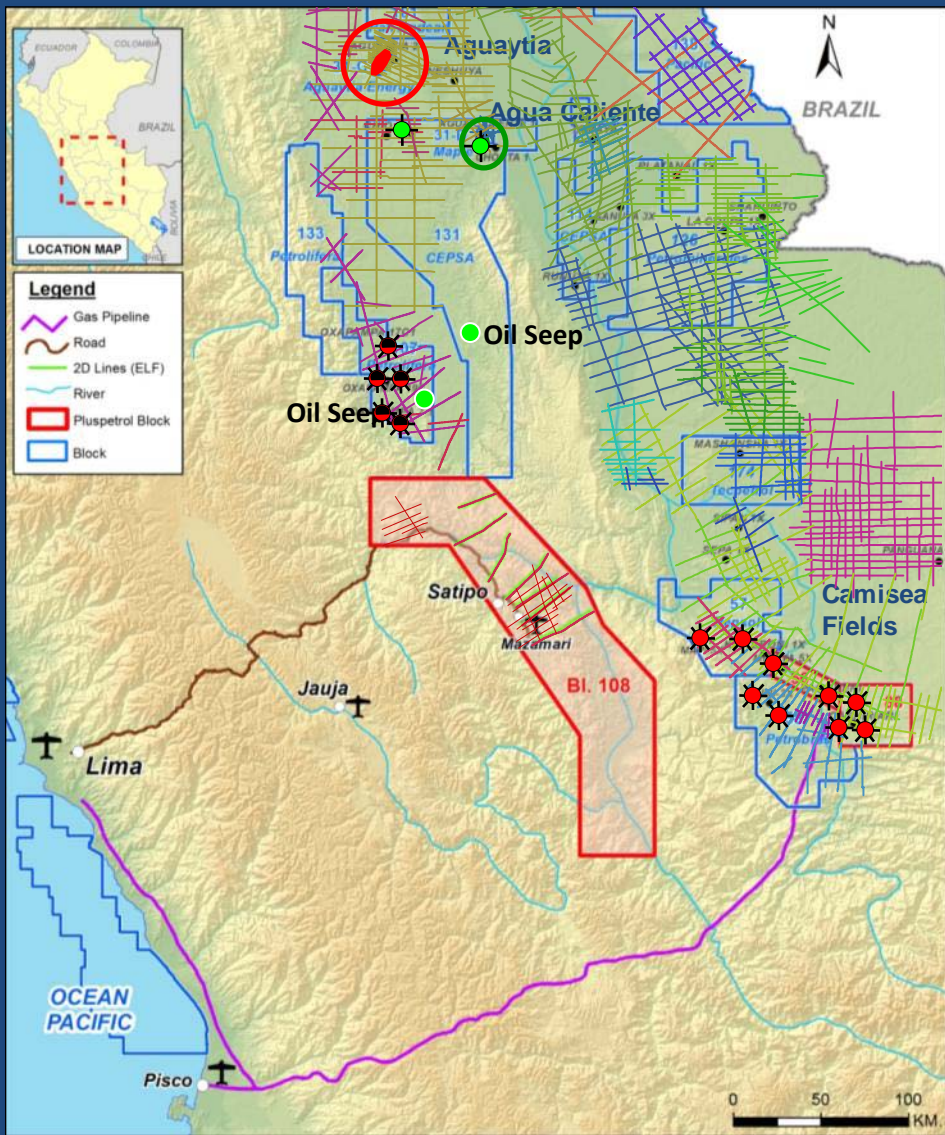
✓ Camisea – Madre de Dios

- 20 Exploratory Wells drilled
- 12 Fields discovered
- 2P Reserves of 4500 MMBOE



FRONTIER EXPLORATION IN ENE BASIN

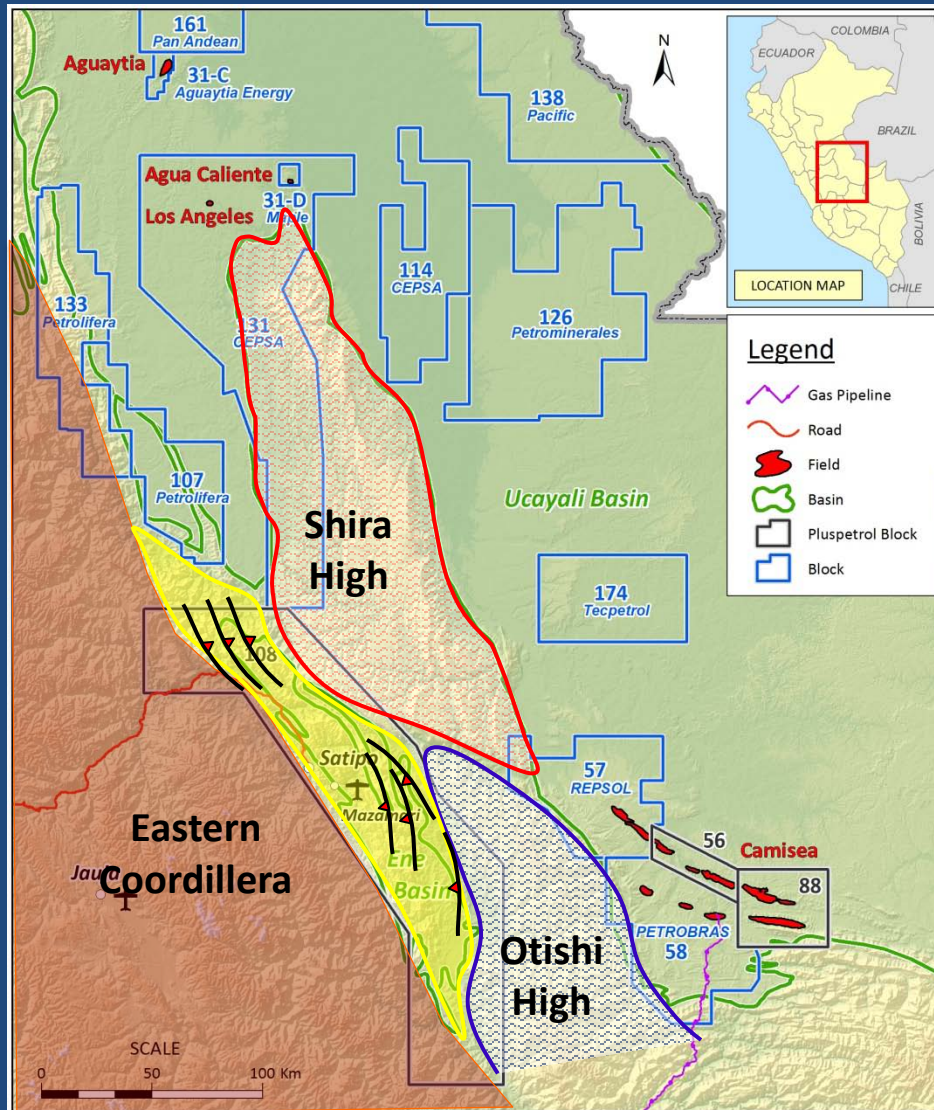
General Information



- Basin Under-explore
- 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

FRONTIER EXPLORATION IN ENE BASIN

Structural Framework

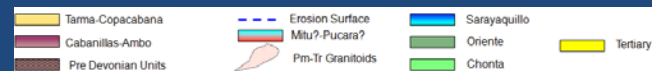
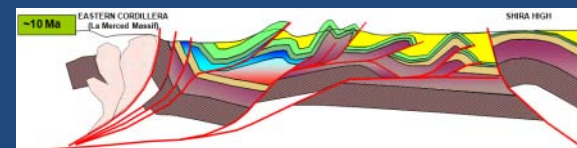
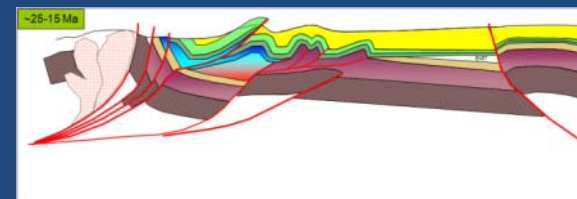
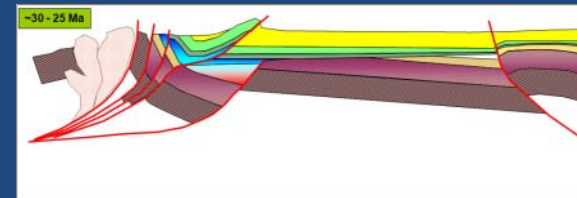
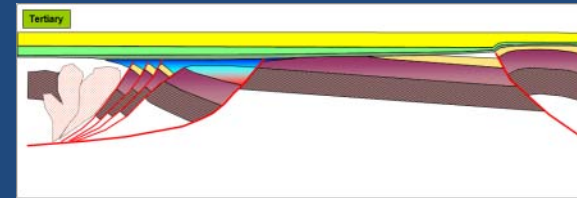
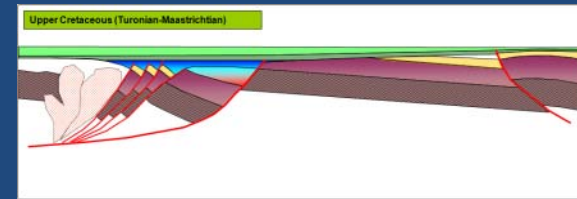
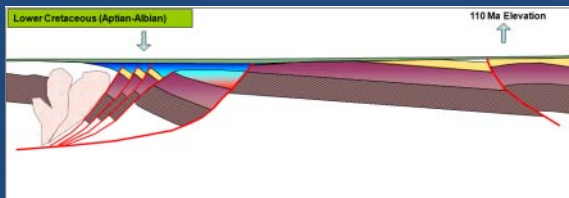
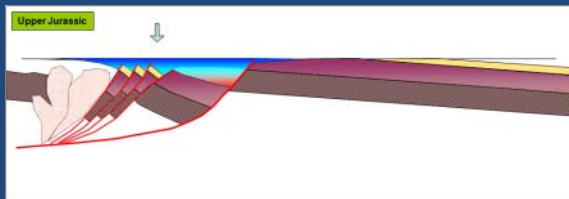
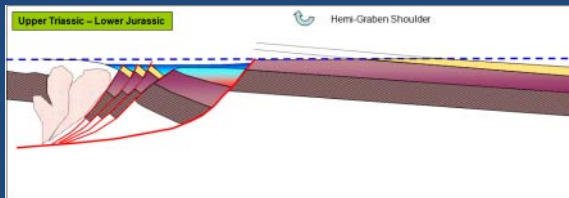
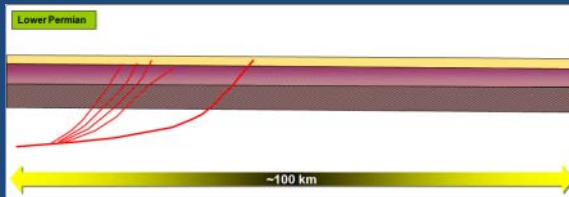


- Located in the fold and thrust belt area of the Peruvian Central Andes.
- Major tectonic blocks interact with each other controlling the structural deformation.
- More than 6000m of sediments from Devonian to Early Tertiary in depocenter.
- Two main Stratigraphic provinces are defined a “Rift domain 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.

FRONTIER EXPLORATION IN ENE BASIN

Basin Evolution

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 develop in the west and the shortening s transferred to the foreland basin producing thin- in the east.

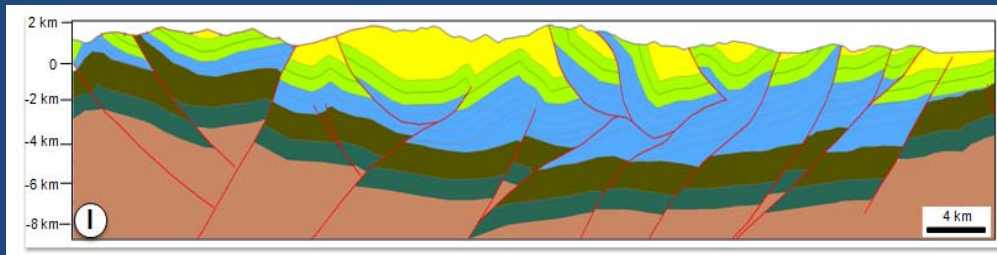


FRONTIER EXPLORATION IN ENE BASIN

Tectonostratigraphic Province

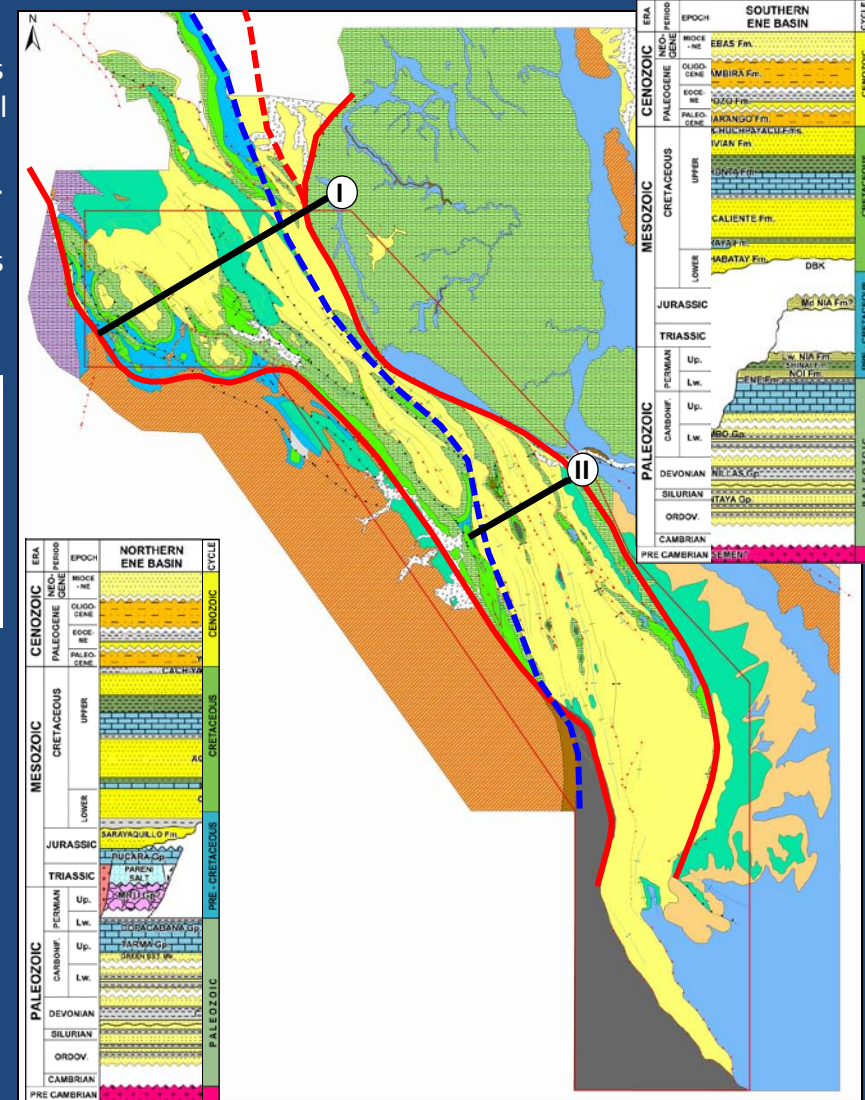
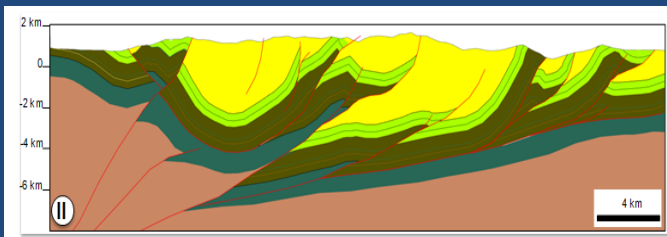
Northern Zone:

- Inversion of Tr-Jr Rift faults, salt domes, and thin-skinned structures detached in the pre-Cretaceous 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.



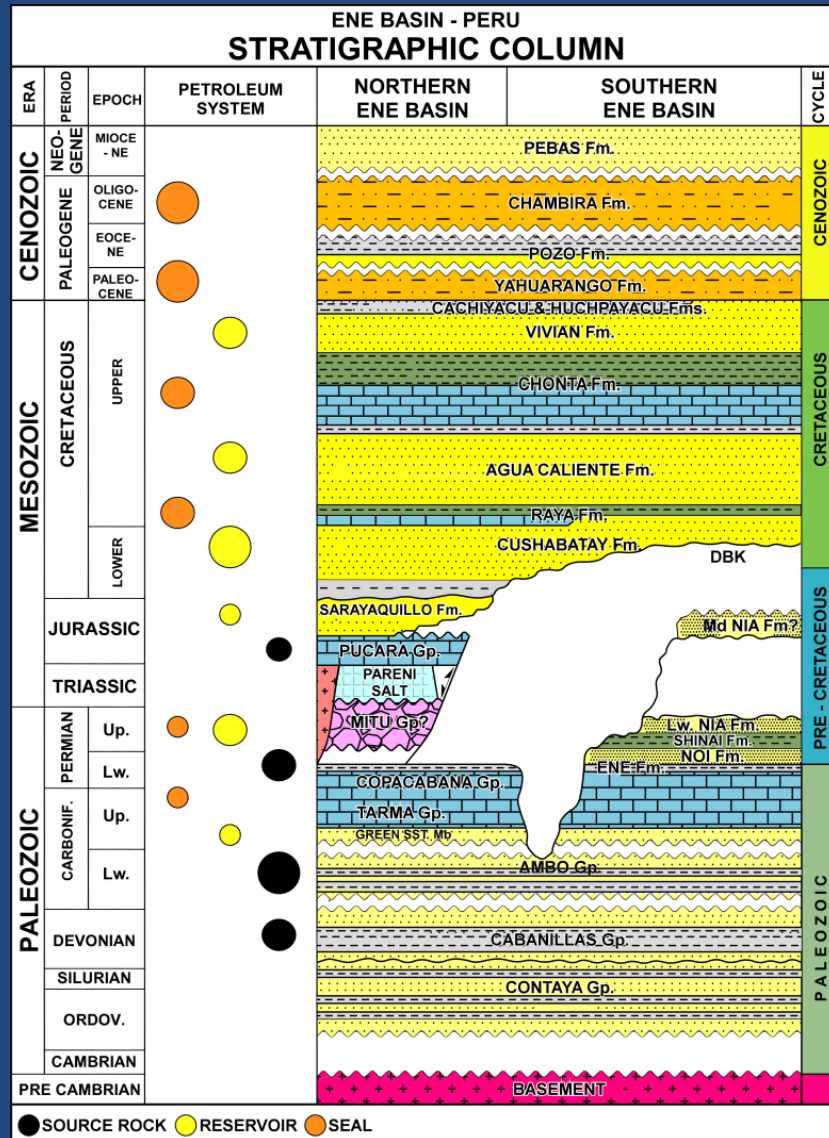
Southern Zone:

- Boca Satipo Play extends southward of the BSSTE prospect.
- Big syncline and a wider area suggest the presence of bigger structures.



FRONTIER EXPLORATION IN ENE BASIN

General Stratigraphic Column



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:

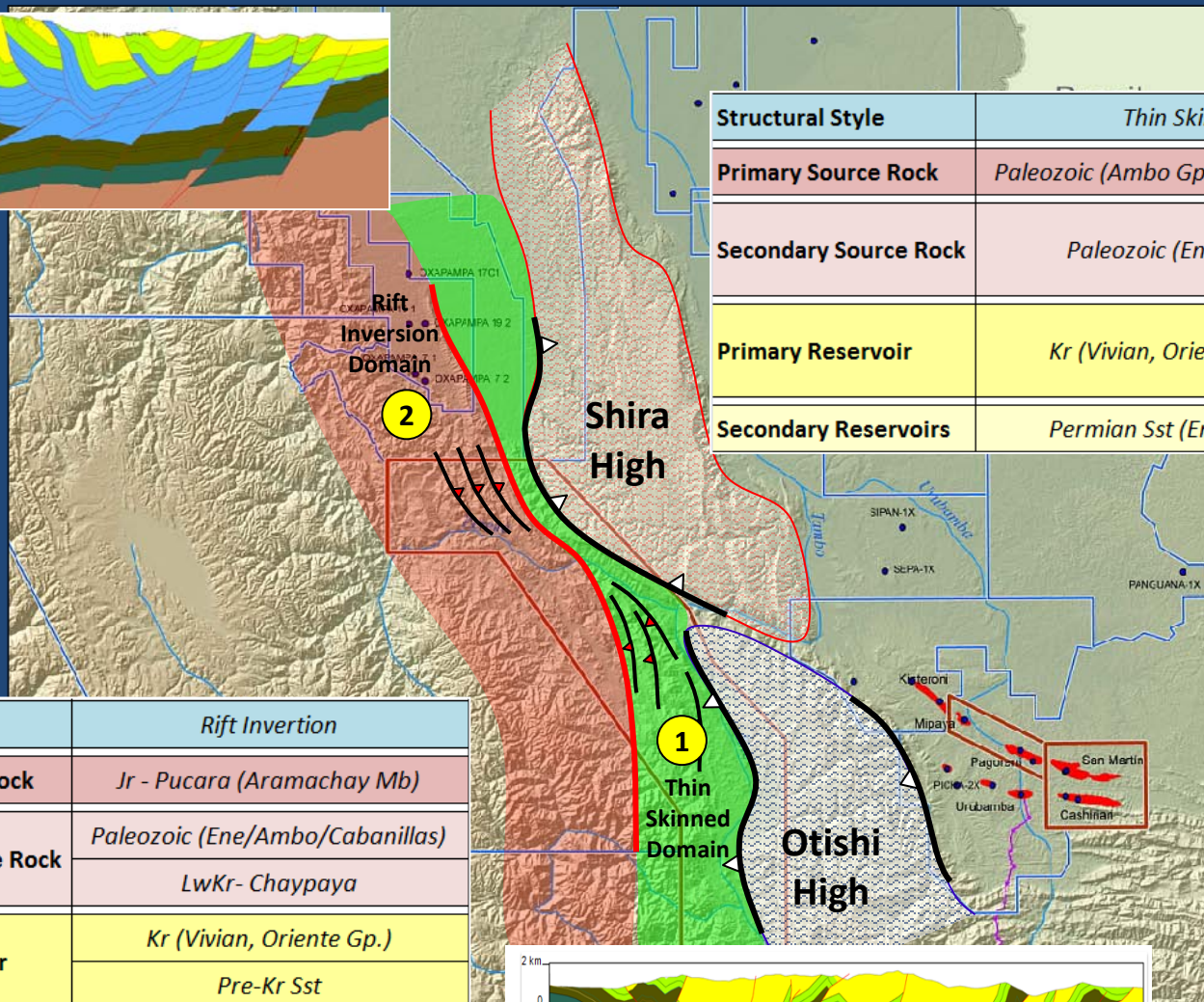
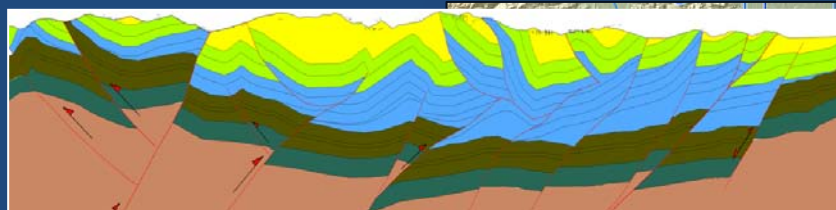
- Clastic units Barremian in age and older were identified below the Oriente Group.
- Pucara Group is present in the eastern cordillera and Pachitea Sub-Basin. Aeolian facies of this cycle could be an important reservoir.

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

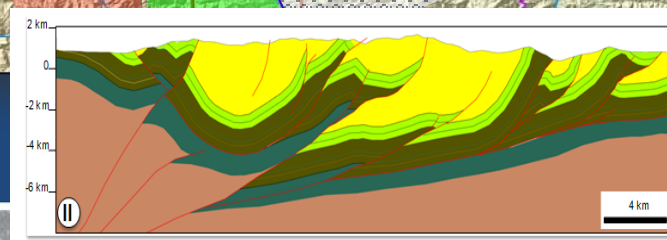
FRONTIER EXPLORATION IN ENE BASIN

Exploration Plays Concept



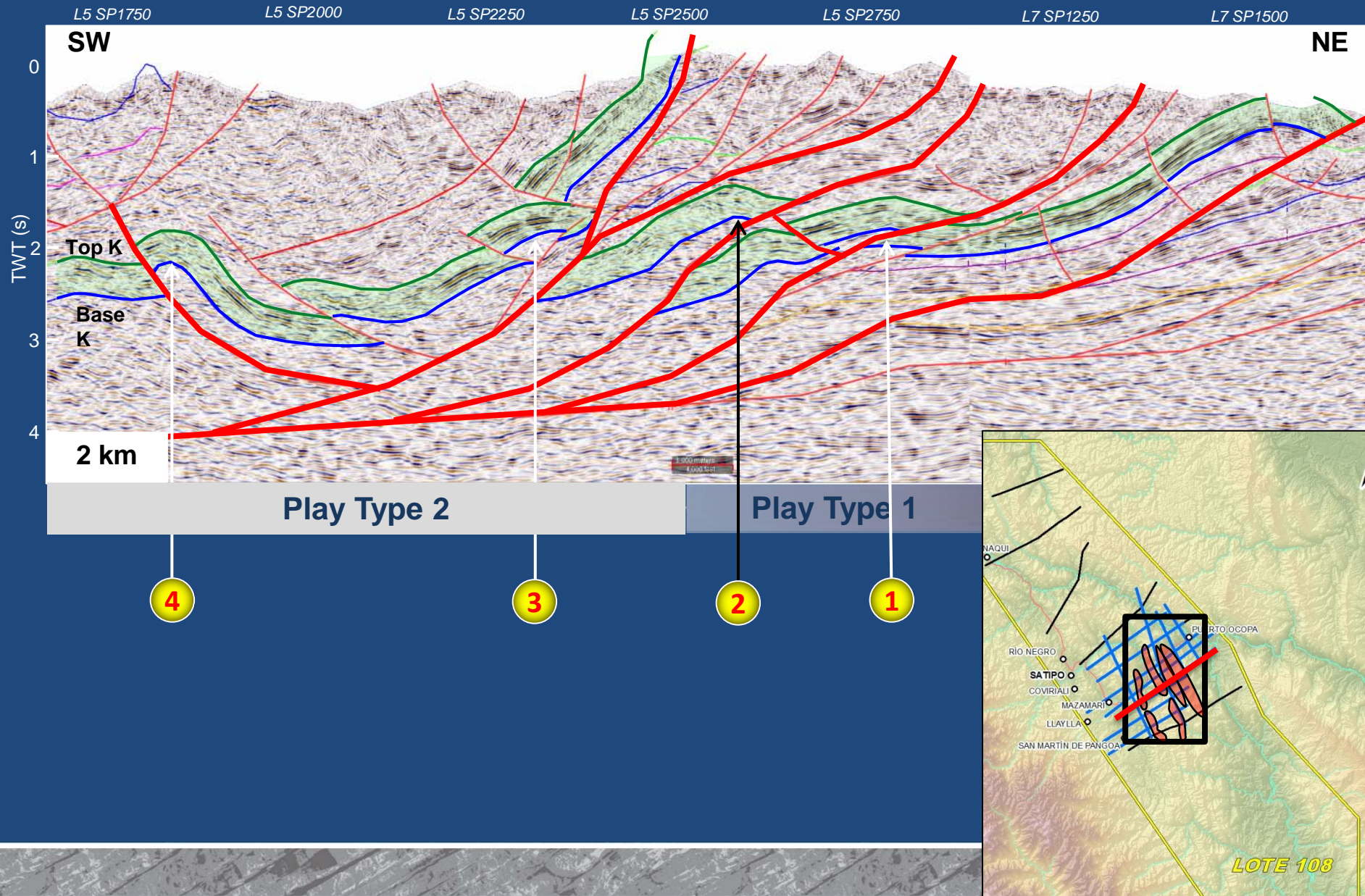
Structural Style	<i>Thin Skin</i>
Primary Source Rock	<i>Paleozoic (Ambo Gp./ Cabanillas)</i>
Secondary Source Rock	<i>Paleozoic (Ene Fm.)</i>
Primary Reservoir	<i>Kr (Vivian, Oriente Gp.)</i>
Secondary Reservoirs	<i>Permian Sst (Ene / Noi)</i>

Structural Style	<i>Rift Inversion</i>
Primary Source Rock	<i>Jr - Pucara (Aramachay Mb)</i>
Secondary Source Rock	<i>Paleozoic (Ene/Ambo/Cabanillas)</i> <i>LwKr- Chaypaya</i>
Primary Reservoir	<i>Kr (Vivian, Oriente Gp.)</i> <i>Pre-Kr Sst</i>
Secondary Reservoirs	<i>Permian Sst (Ene / Noi)</i>



FRONTIER EXPLORATION IN ENE BASIN

Seismic Interpretation



FRONTIER EXPLORATION IN ENE BASIN

Hydrocarbon Occurrences

11) Well Oxapampa 7-1

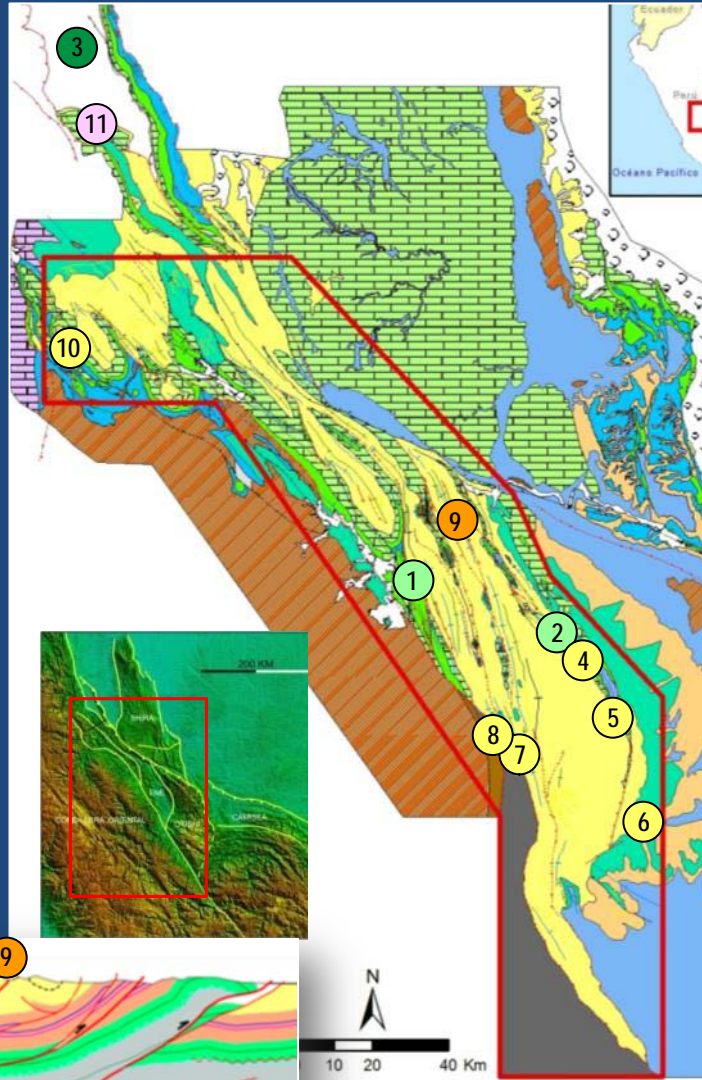
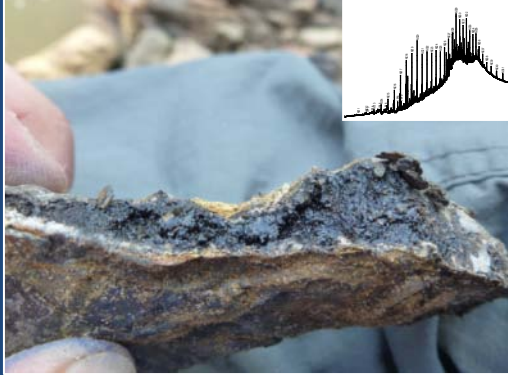
- Chonta Fm outcropping
- Gas Chromatography +C4
- Res: Cushabatay Fm (134m)

10) Fluid Inclusions

@ Cushabatay, Tmax 115-130°C

9) Oil Impregnation in Boca Satipo fault

Origin: Ambo.



1) Oil Stain

CEL-04

2) Outcrop Sample

Ene Fm SST with oil, fluorescence bright yellow and cut.

3) Gas Seep

Oxapampa 19-1 Well Head

4) Fluid Inclusions

@ Ene, 34-36°API

5) Fluid Inclusions

@ Ene, 12-15°API

6) Fluid Inclusions

@ Ene, >52°API

7) Fluid Inclusions

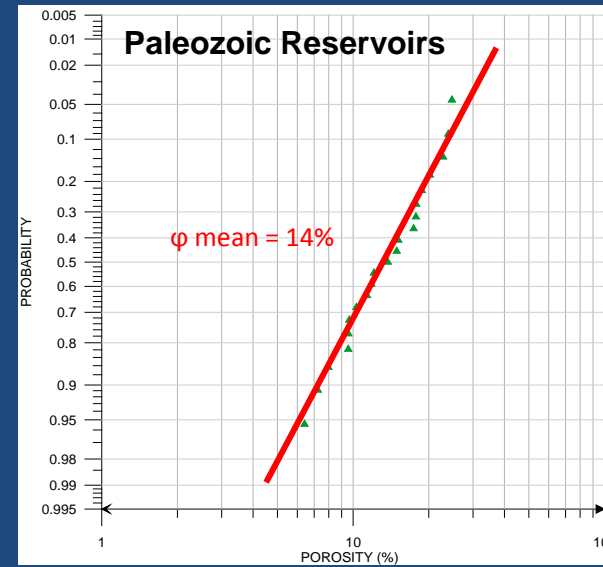
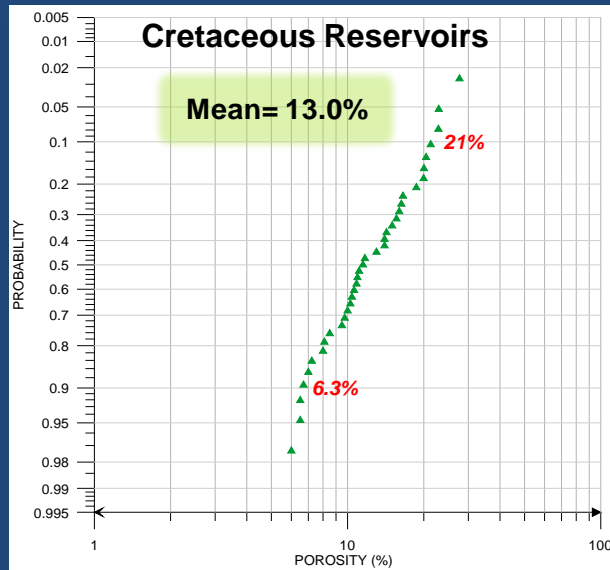
@ Ene, 34-36°API

8) Fluid Inclusions

@ Ambo, 36-41°API

FRONTIER EXPLORATION IN ENE BASIN

Reservoirs Quality



Peruvian Subandean Basins

- ✓ Northern Foreland Basin (Marañón): Well Explored and Successful, Required change in exploration ideas for bigger discoveries.
- ✓ Southern/Central Foreland Basins: Underexplored (specially Madre de Dios basin), small historic discoveries in the Ucayali basin. Stratigraphic trap is a promising exploration play in Madre de Dios.
- ✓ Fold-and-thrust belt: Largely unexplored (specially in the north). TFB of Camisea – MDD shows High potential for big discoveries.
- ✓ Southern Ene Basin could be the continuation of the play Camisea-MDD, by the end of this year an exploratory well will be drilled.