Adding Hydrocarbon Reserves in the Uncertainty of a Structurally Complex Area, Llanos Foothills, Colombia*

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Abstract

This paper explains how Equion Energia has been successful producing hydrocarbon in a complex area, where the uncertainty and the economical investment for finding the reservoirs are high. The Piedemonte Production Contract is located in the central area of the Llanos Foothills of the Eastern Cordillera in Colombia. This Contract is characterized by a high productivity of hydrocarbons, related to multiple structural traps that make as part of an antiformal stack duplex. The recoverable volume of hydrocarbon is between 150 to 250 MB of gas condensate. The average production of a typical well is 5.000 barrels. The total depth of the wells is 13.000 up to 20.800 feet; this depth is reached after drilling a stratigraphic sequence composed by Tertiary and Cretaceous sediments. The hydrocarbon production comes from Maastrichtian, Paleocene and Eocene sandstones that are involved into faulted anticlines that were mainly formed during the Andean orogeny. The area has been interpreted using 451 km^2 of 3D - PSDM seismic data, information of 37 production wells and detailed surface geology. The combined effect of a rough topography, a complex structural framework, fair quality of the seismic data and limited well information generates a high uncertainty for the positioning of new wells and an optimum management of the hydrocarbon fields. Here, we present the methods used by the Equión team in the integration and interpretation of 3D seismic, geological data, dynamic data (pressures and fluids) and 2D-3D structural modeling that have led to the substantial increment of new reserves. The application of structural geology fundamentals has allowed to successfully manage the risk factors; for this reason, in the Piedemonte License, no dry wells have been drilled. The most important result is that using these methodologies, it has been possible to find consecutively new structural traps and reservoirs. It led to increase the value of the hydrocarbon in place in a range of 50 - 150 MMstb in the Piedemonte Contract, and thus, expanding the portfolio of future new wells in the area. Finally, these methodologies are replicable in order to achieve exploratory success in areas where structural geology is very complex, and the essential tools do not provide the most desirable information.

Adding Hydrocarbon Reserves in the Uncertainty of a Structurally Complex Area Llanos Foothills, Colombia

Roberto Linares

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equion

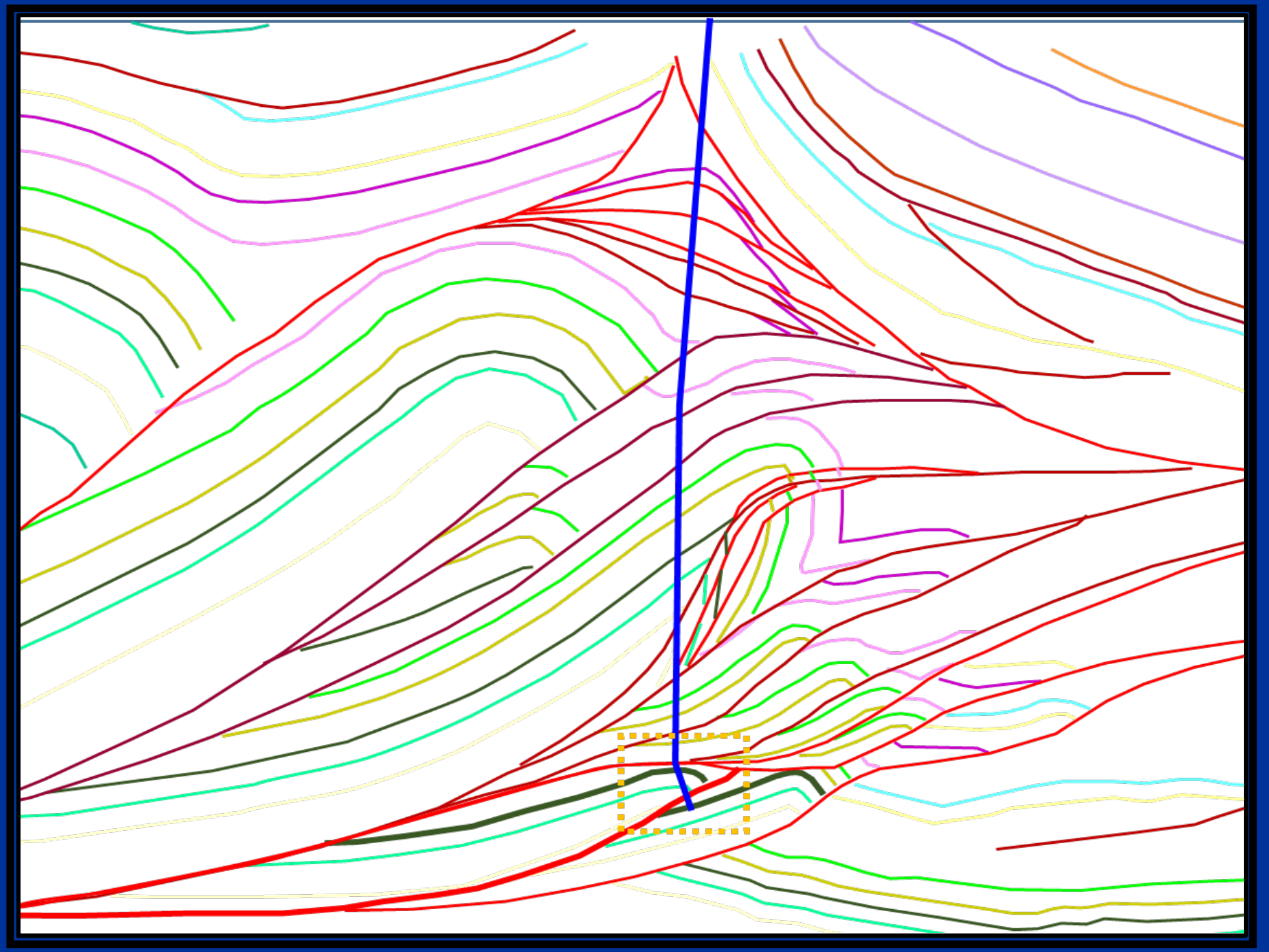
Energía para la vida

Uncertainty in complex areas could be either

a Stopper

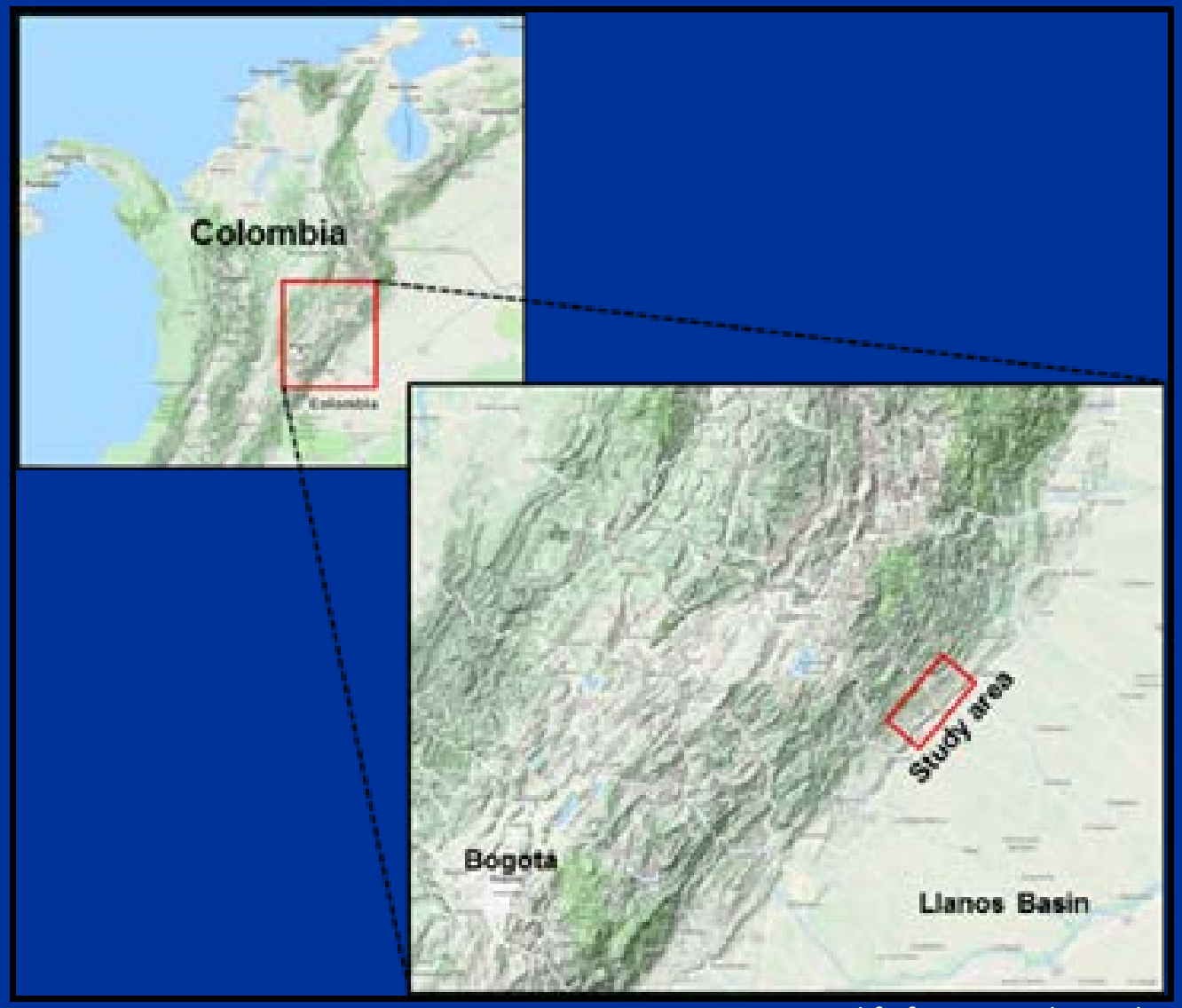
Or

a Source of opportunities



Click to view video

LOCATION



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CONCLUSIONS

I

This methodology led to increase the OOIP in a range of 50 - 150 MMstb

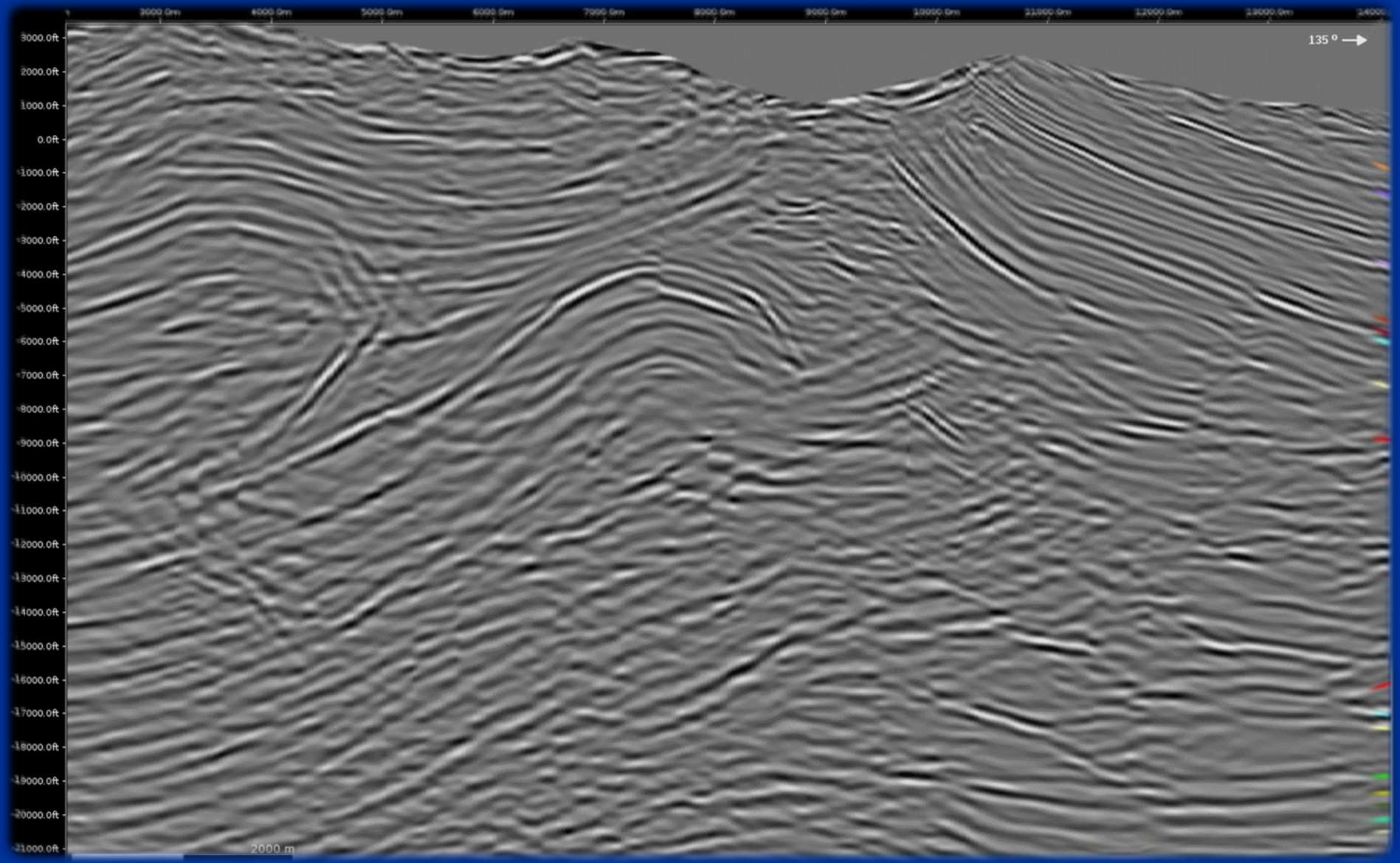
II

The structural modeling diminishes the uncertainty in complex areas.

III

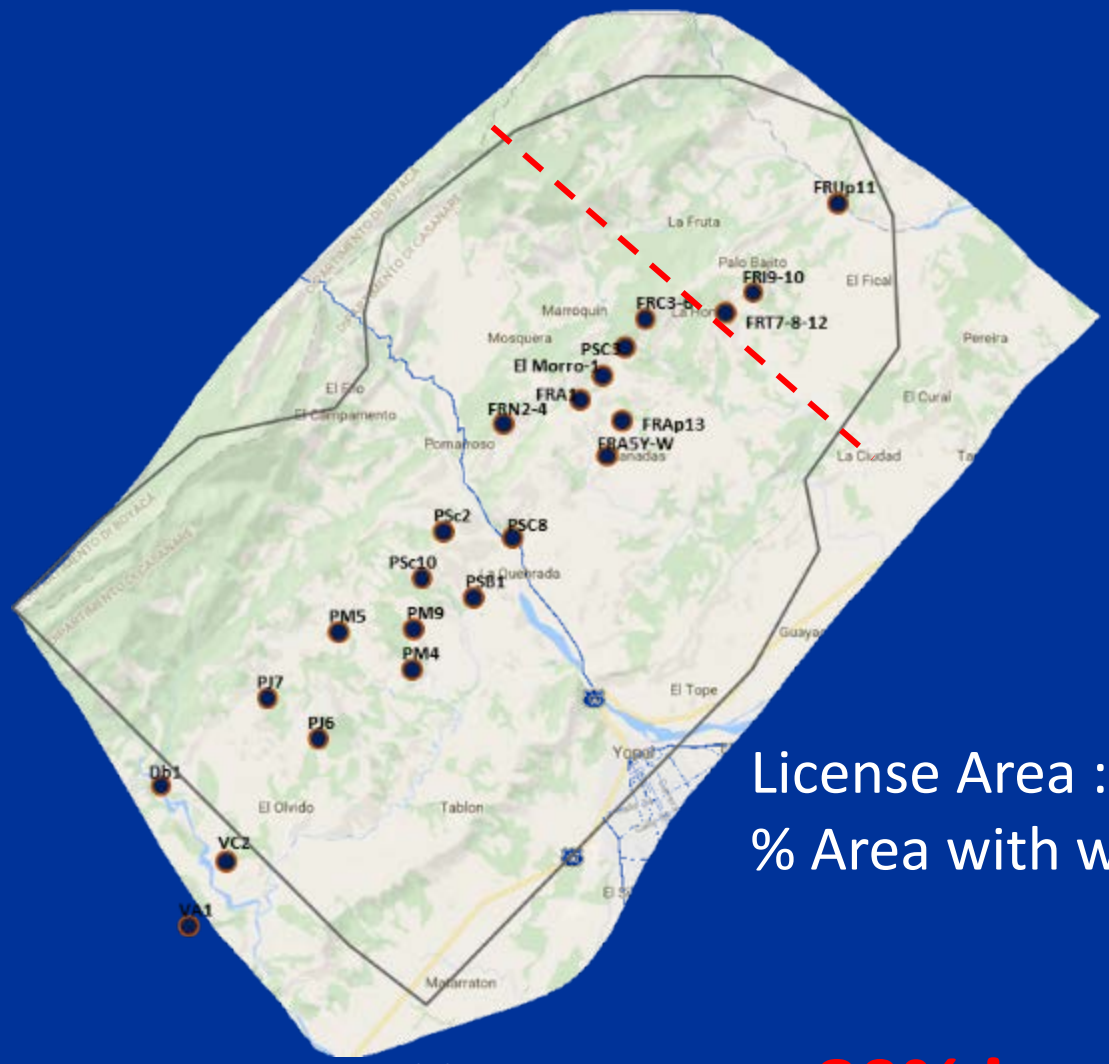
The understanding of the complexity allowed to create a portfolio of new development wells.

Seismic Data Quality - Structural Complexity



WELL DATA

No.	Pozo	Spudded	Campo
1	El Morro -1	1972	Morro
20 años sin perforar pozo nuevo			
2	Volcanera A-1	1992	V
3	Florena A-1	1994	F
4	Pauto Sur B-1X	1994	P b
5	Volcanera C-2Z	1996	P V
6	Pauto Sur C-2fw	1996	P P
7	Florena N-2f	1996	F
8	Florena C-3f	1996	F
9	Floreña N-4	1997	F
10	Floreña A-5pw	1997	P P
11	Pauto Sur C-3m	1997	Morro
12	Florena C-3Z	1997	F
13	Florena C-3ST1Z	2000	F
14	Florena A-1X	2001	F
10 años sin perforar pozo nuevo			
15	Florena C-6	2007	F
16	Floreña A-5pw	2008	P P
17	PTM4	2009	P
18	Dele B1ZST1Y	2010	P P
19	Floreña N-4ST1py	2010	F P
20	Florena T-7	2010	F P
21	Florena T-8	2011	F
22	Pauto M-5	2011	P
23	Florena N-2fu	2011	F
24	Pauto J-6Z	2012	P
25	Florena A-1XST1	2012	F
26	Pauto J-7X	2012	P P
27	Pauto Sur C-8	2012	P Pb
28	Florena A-1XST1Z	2013	F
29	Floreña I-9	2013	F
30	Floreña Ip-10	2013	F P P
31	Floreña Up-11Z	2014	P P P P
32	Floreña Tp-12	2014	F P P P P
33	Floreña Ap-13	2014	F P P
34	Floreña If-14	2015	F
35	Pauto Mp-9	2015	P P P b g
36	Pauto sur Cp10	2015	P P P b g
37	FRIp15w	2016	P P P P



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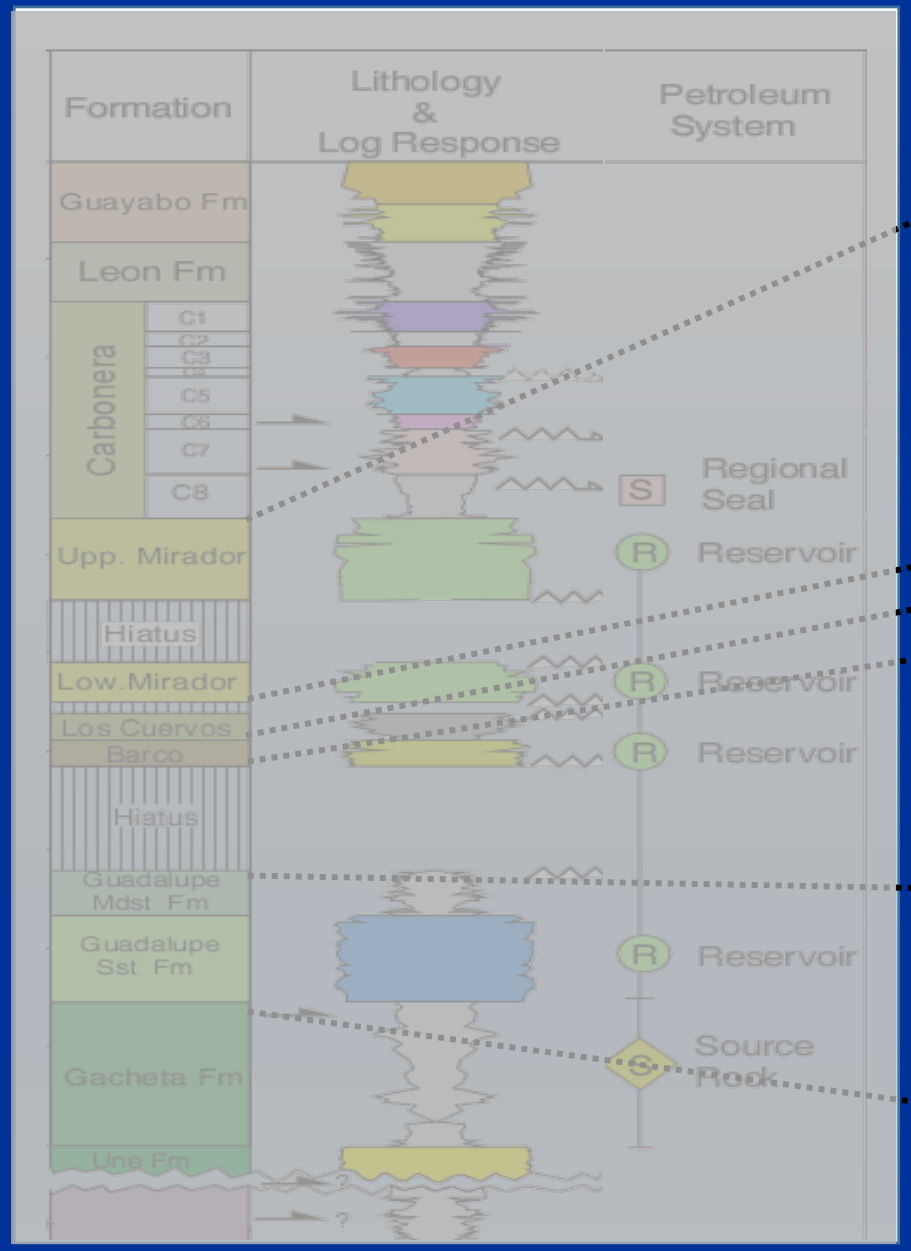
License Area : 257 km²

% Area with well control: 20%

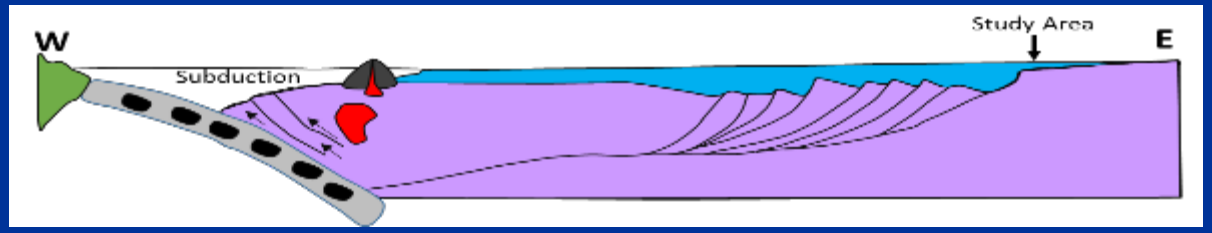
80% is unknown

STRATIGRAPHY

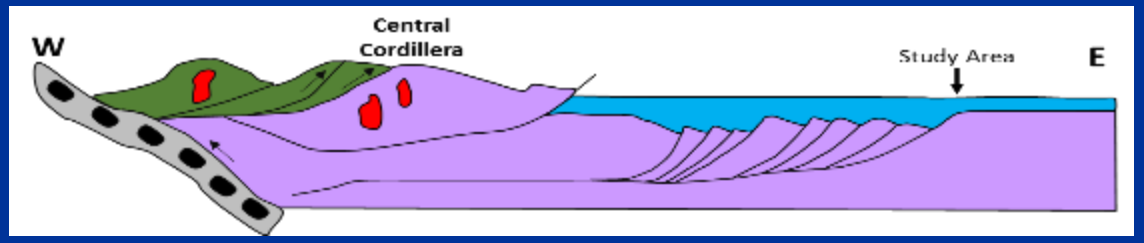


TECTONIC EVOLUTION

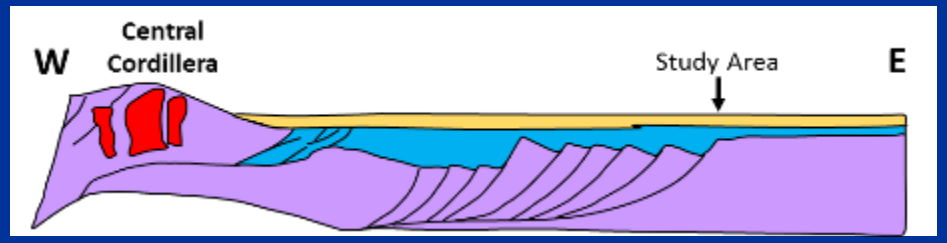
1. Back-arc rifting (Jurassic to Early Cretaceous), related to Farallon plate subduction and the separation of North and South America in the proto-Caribbean



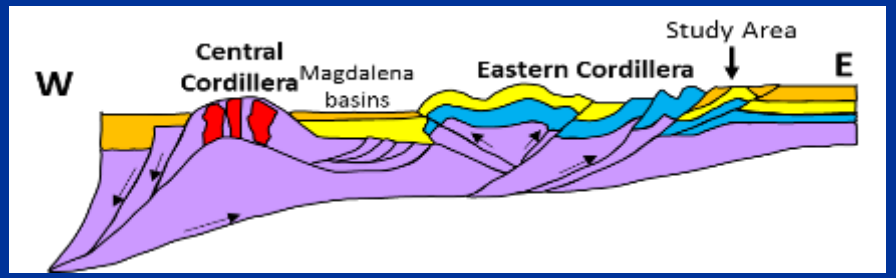
2.Thermal subsidence (Cretaceous)



3. Accretion of the Western Cordillera (Latest Cretaceous to early Tertiary) and creation of a foreland basin that persisted until the middle Miocene to Present.



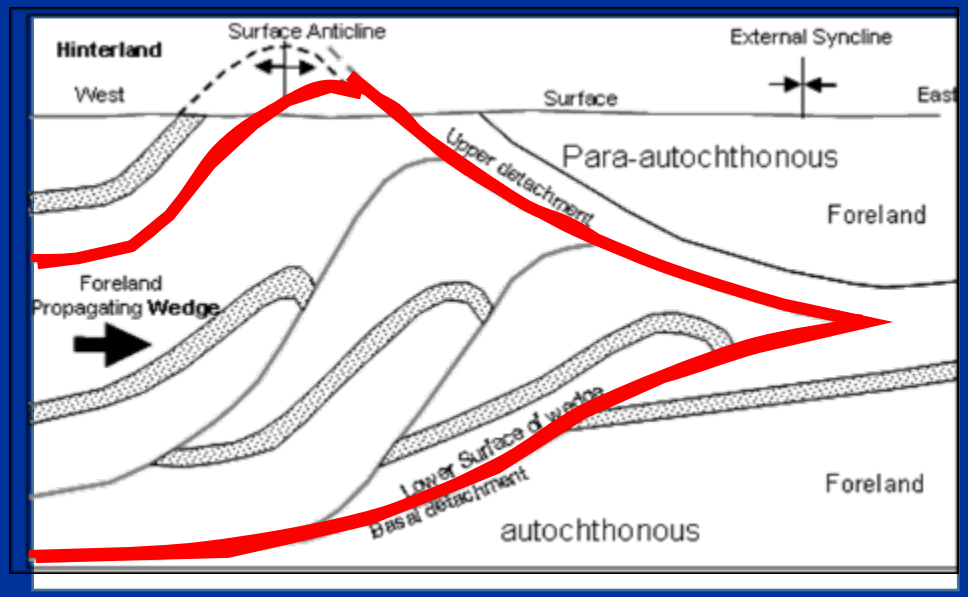
4. Inversion of the rift basin and formation of the Eastern Cordillera (Oligocene to Present).



From Cooper et al.

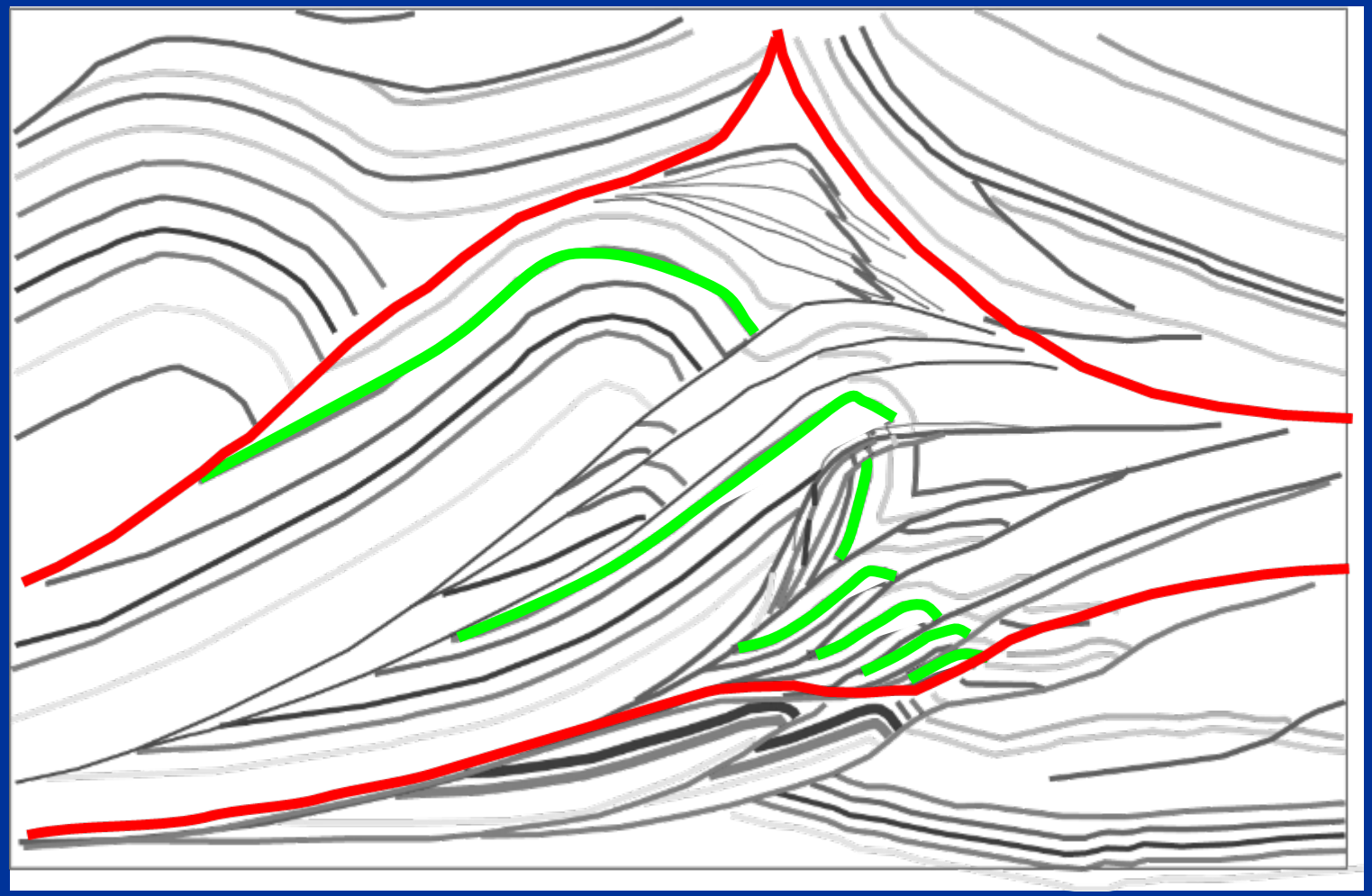
STRUCTURAL SETTING

Theoretical Model



From Mackay, P.A. 1996.

Piedemonte Model

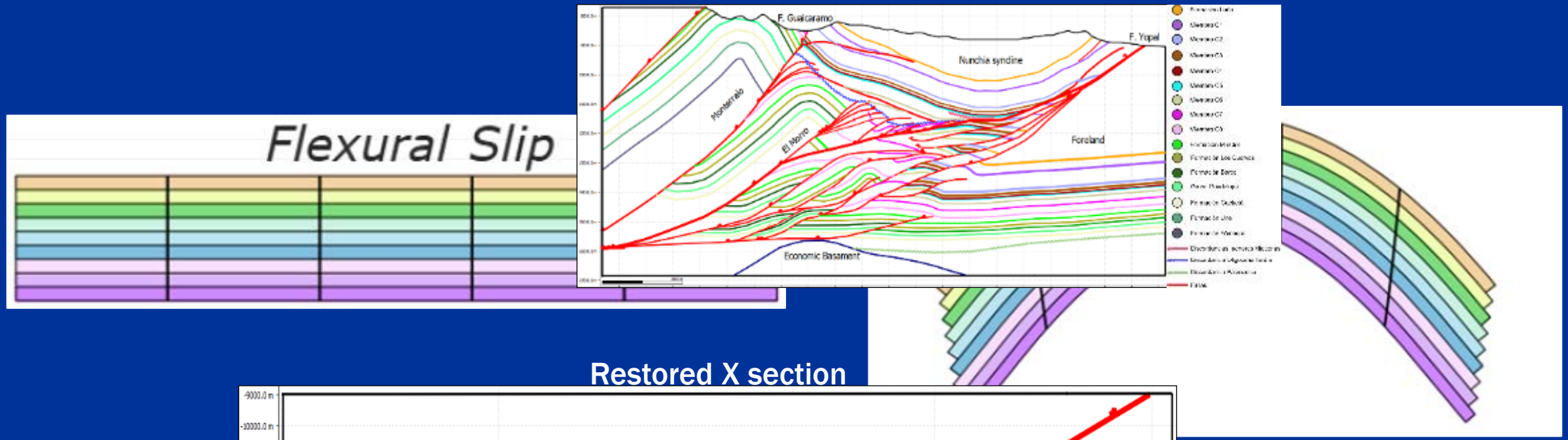


FUNDAMENTAL I

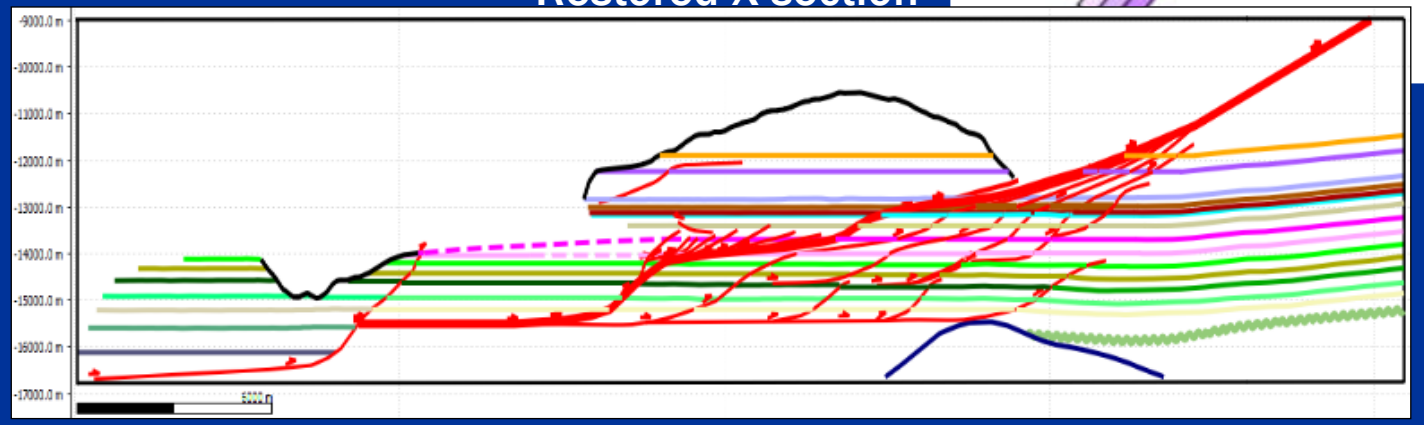
FUNDAMENTAL I

The lengths of the pre-tectonic (restored) horizons should be consistent with the present-day (deformed) interpretation *(Chamberlain, 1910; Dahlstrom, 1969).*

Balanced X section

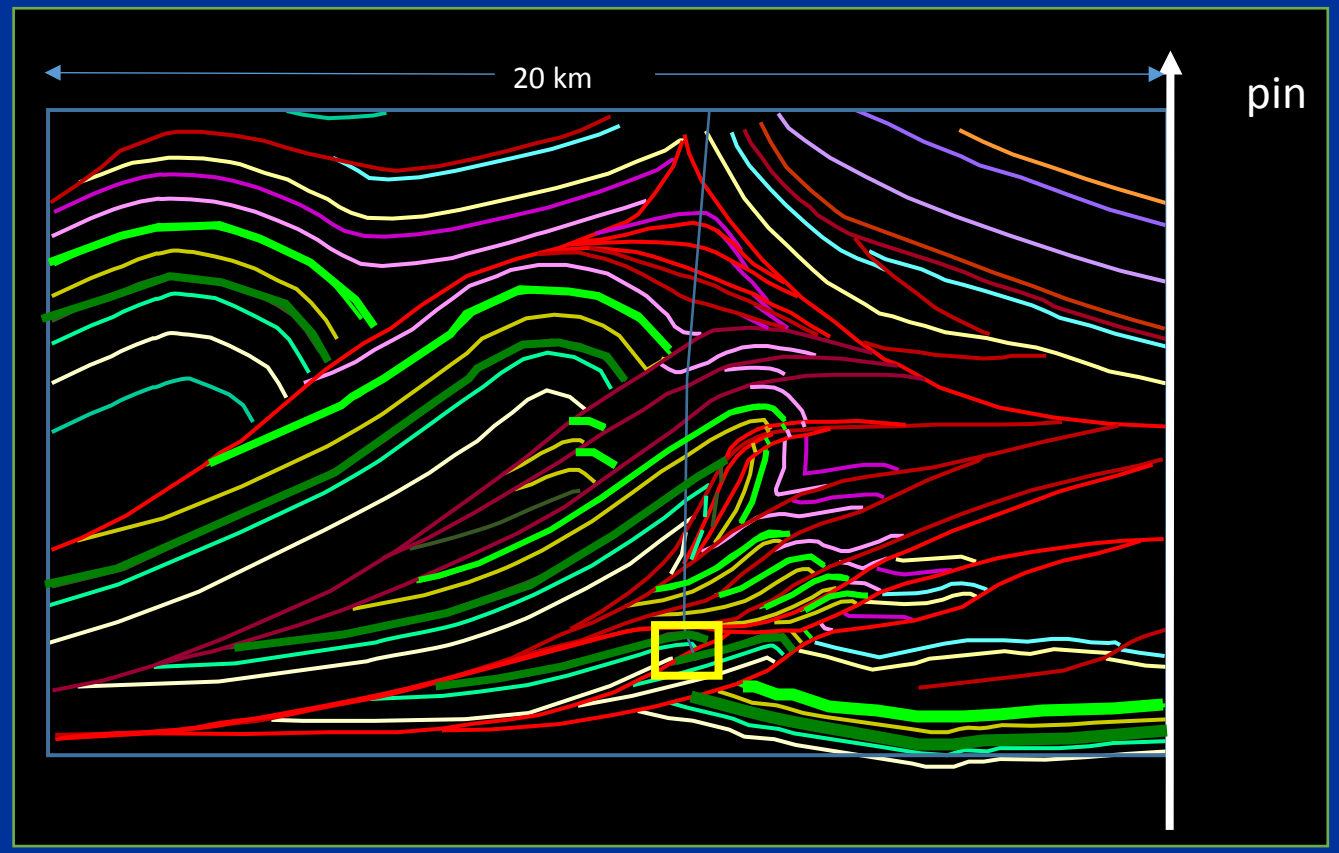


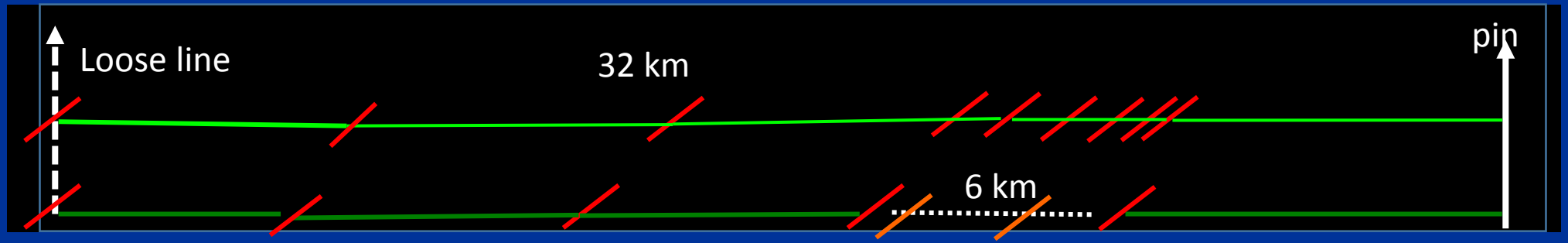
Restored X section



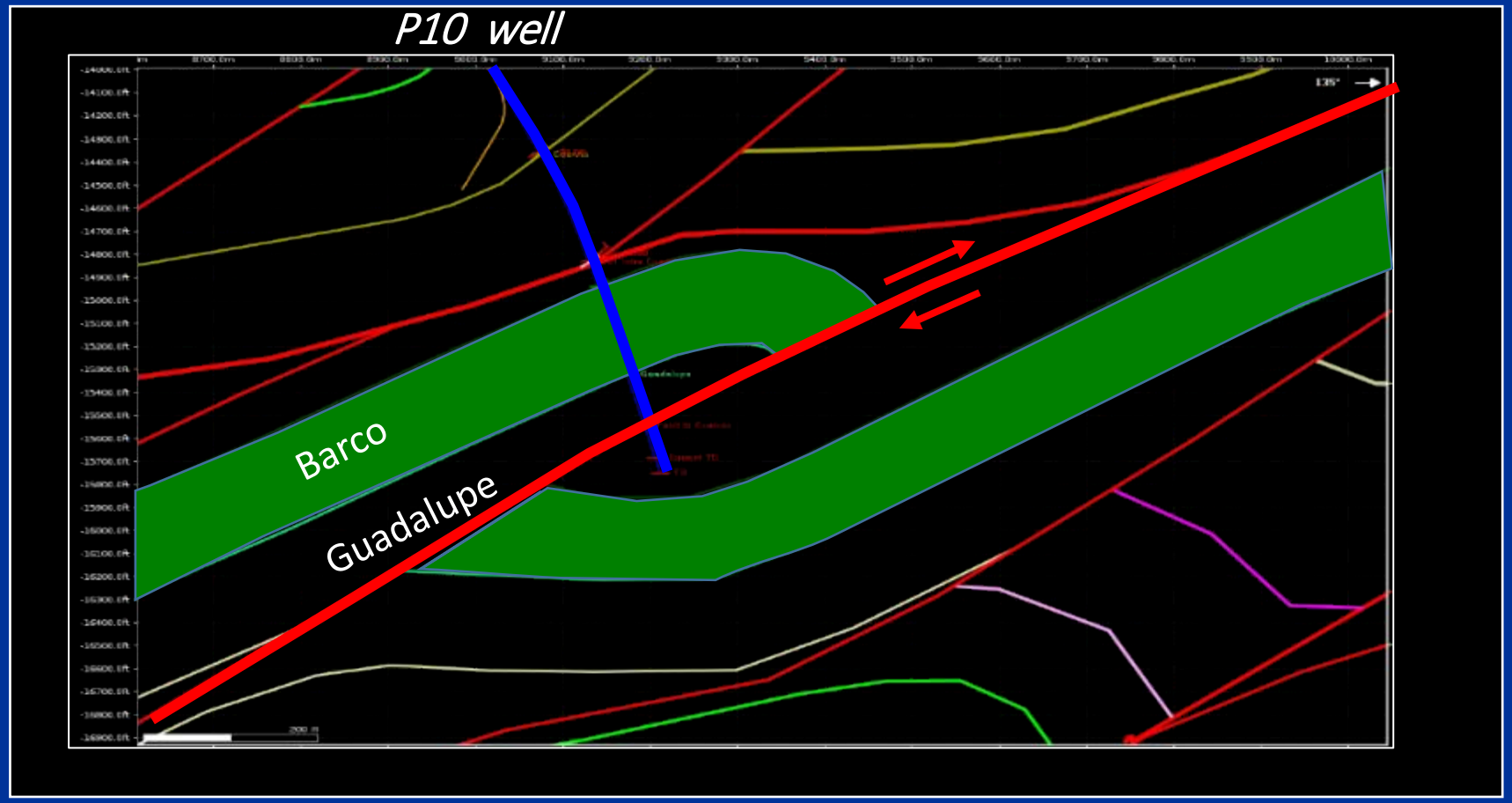
From: Best practices in 2D sequential restoration. Midland Valley

FUNDAMENTAL I





RESULTS

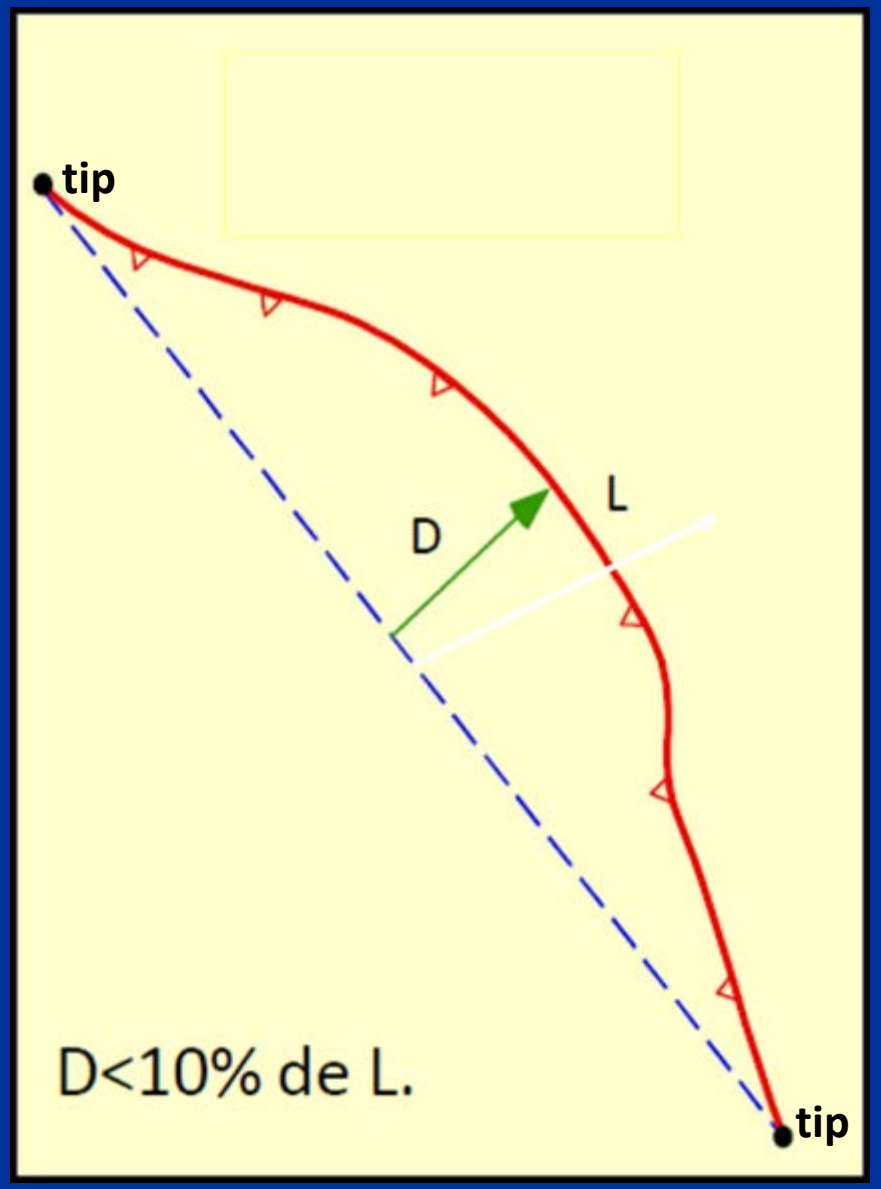


- Added 35 to 60 MMSTB to the Barco and Guadalupe OOIP
- The IOR of P9 and P10 from Barco and Guadalupe is 6800 BOPD

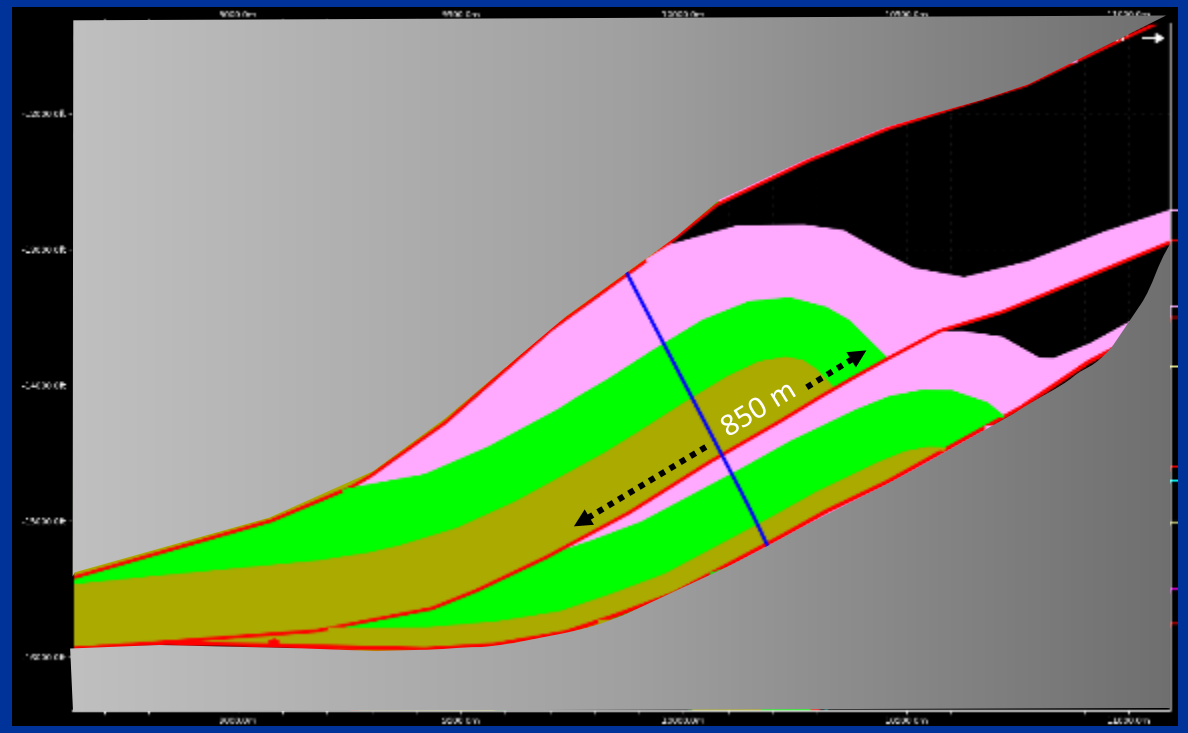
FUNDAMENTAL II

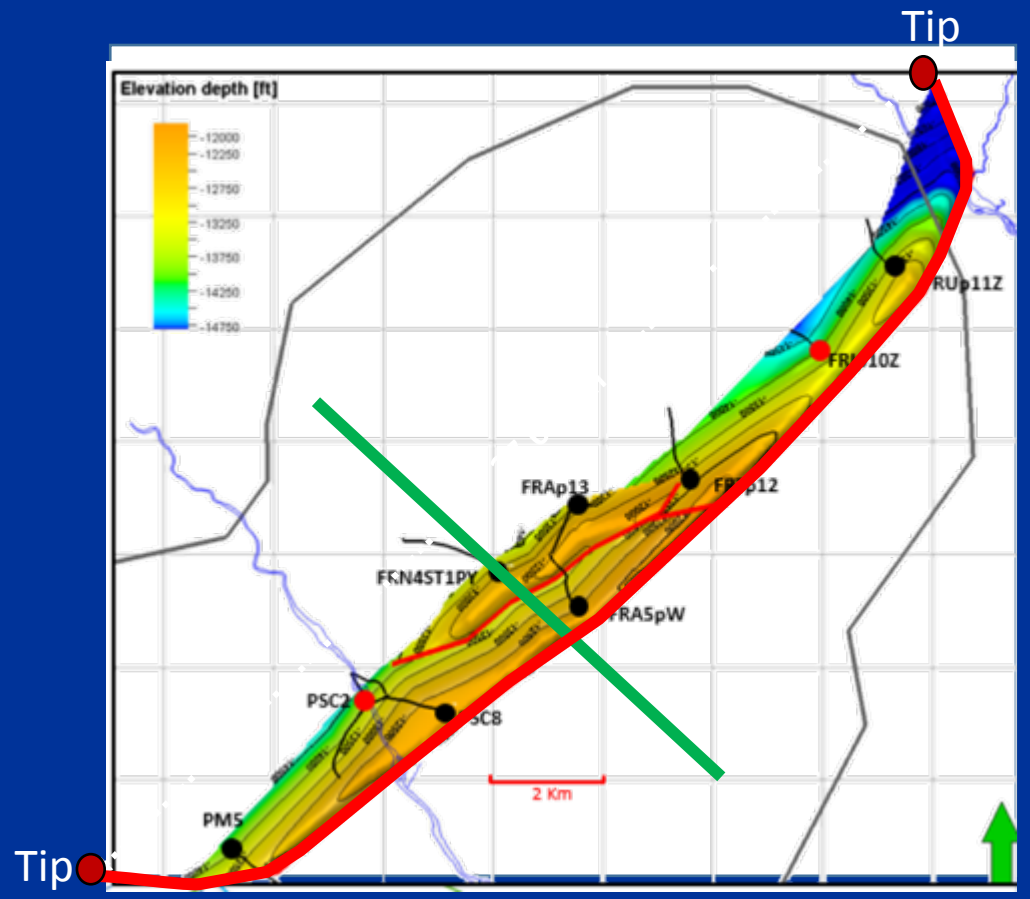
FUNDAMENTAL II

Bow and Arrow rule: "the maximum displacement of a reverse fault is about 10% of the length of the trace that join the tips of the fault in map view" Elliot, 1976



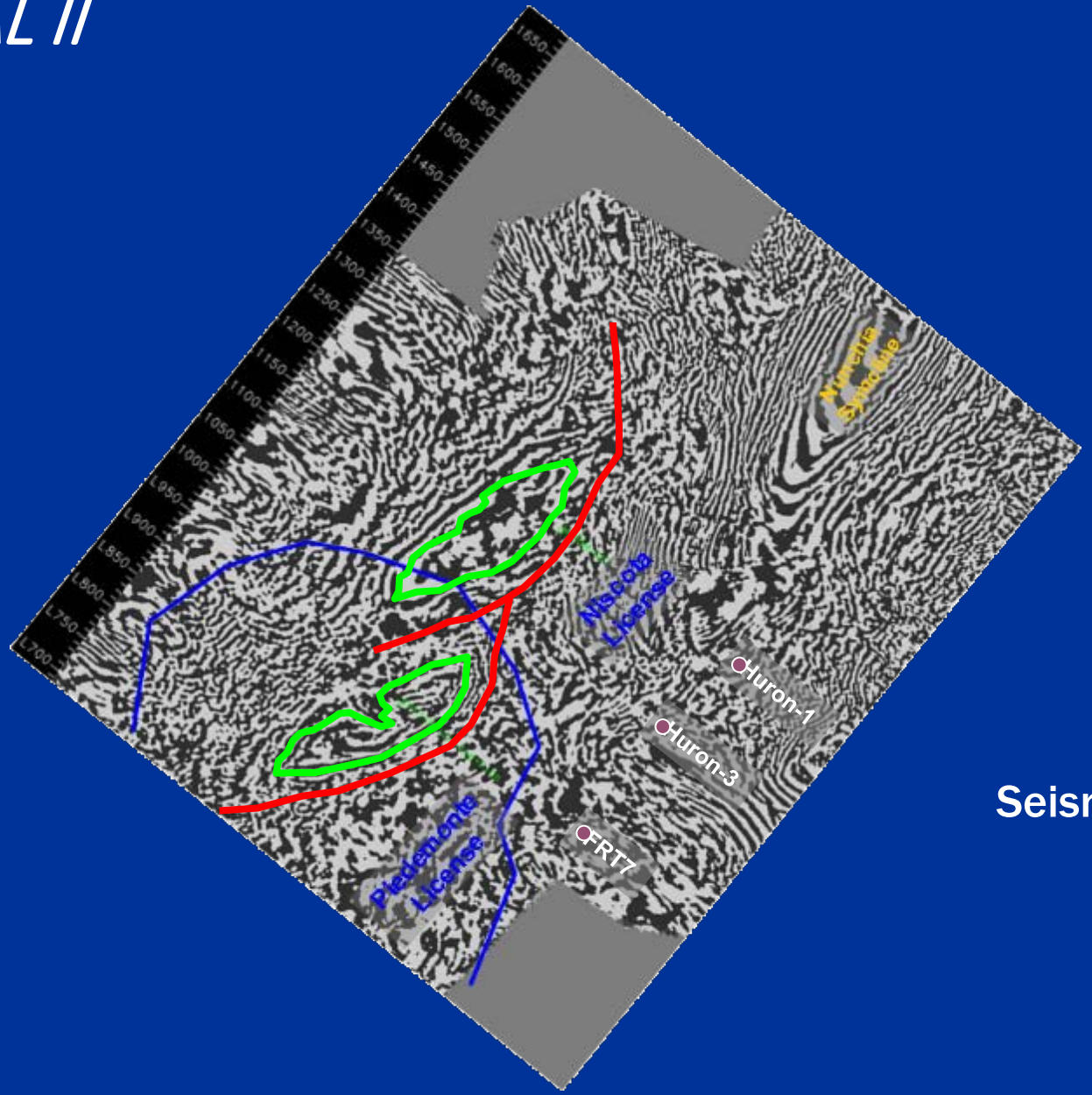
FUNDAMENTAL II





850 m are 3% of the fault length

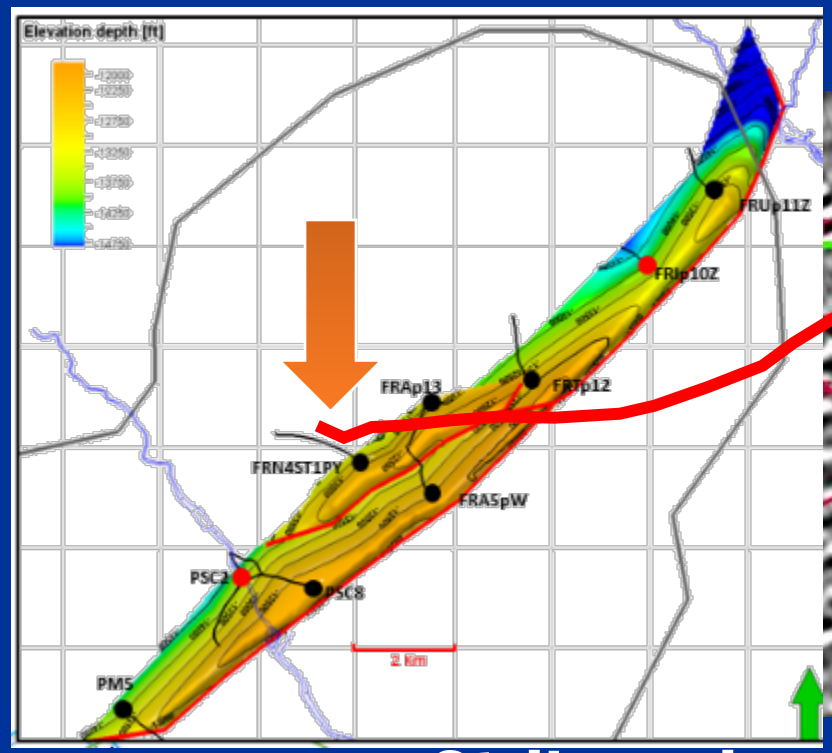
FUNDAMENTAL II

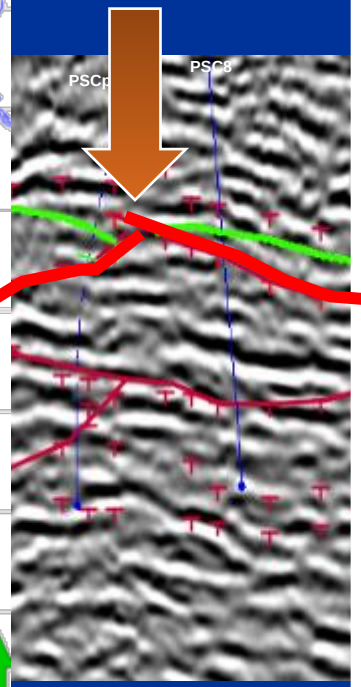


Seismic Depth slice

FUNDAMENTAL II

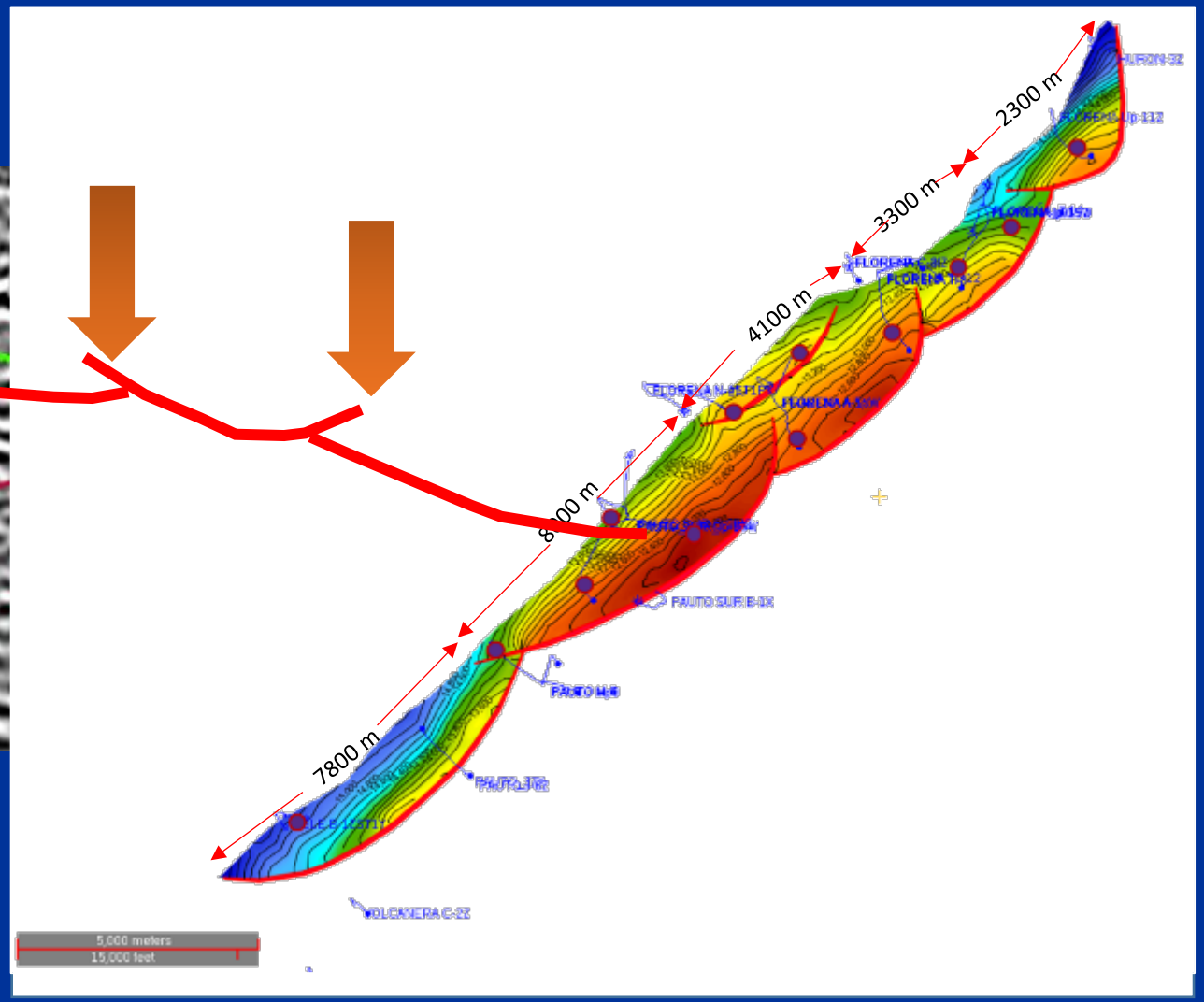
OLD INTERPRETATION



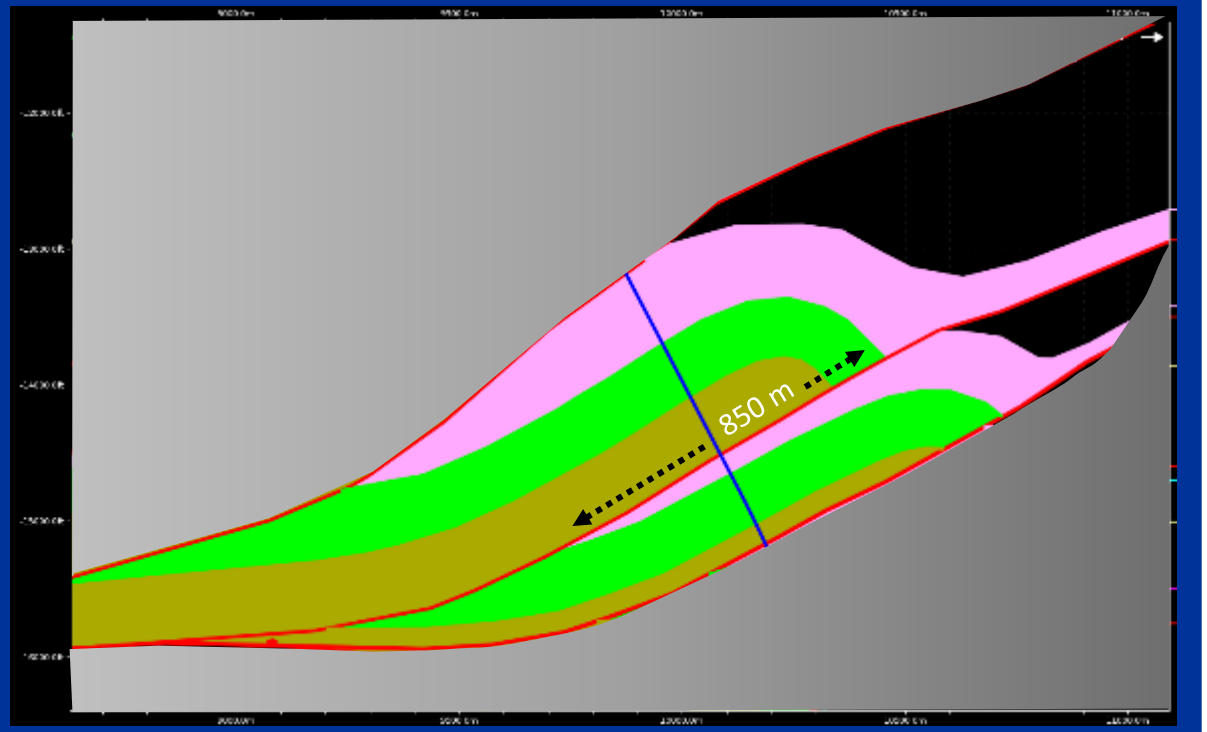


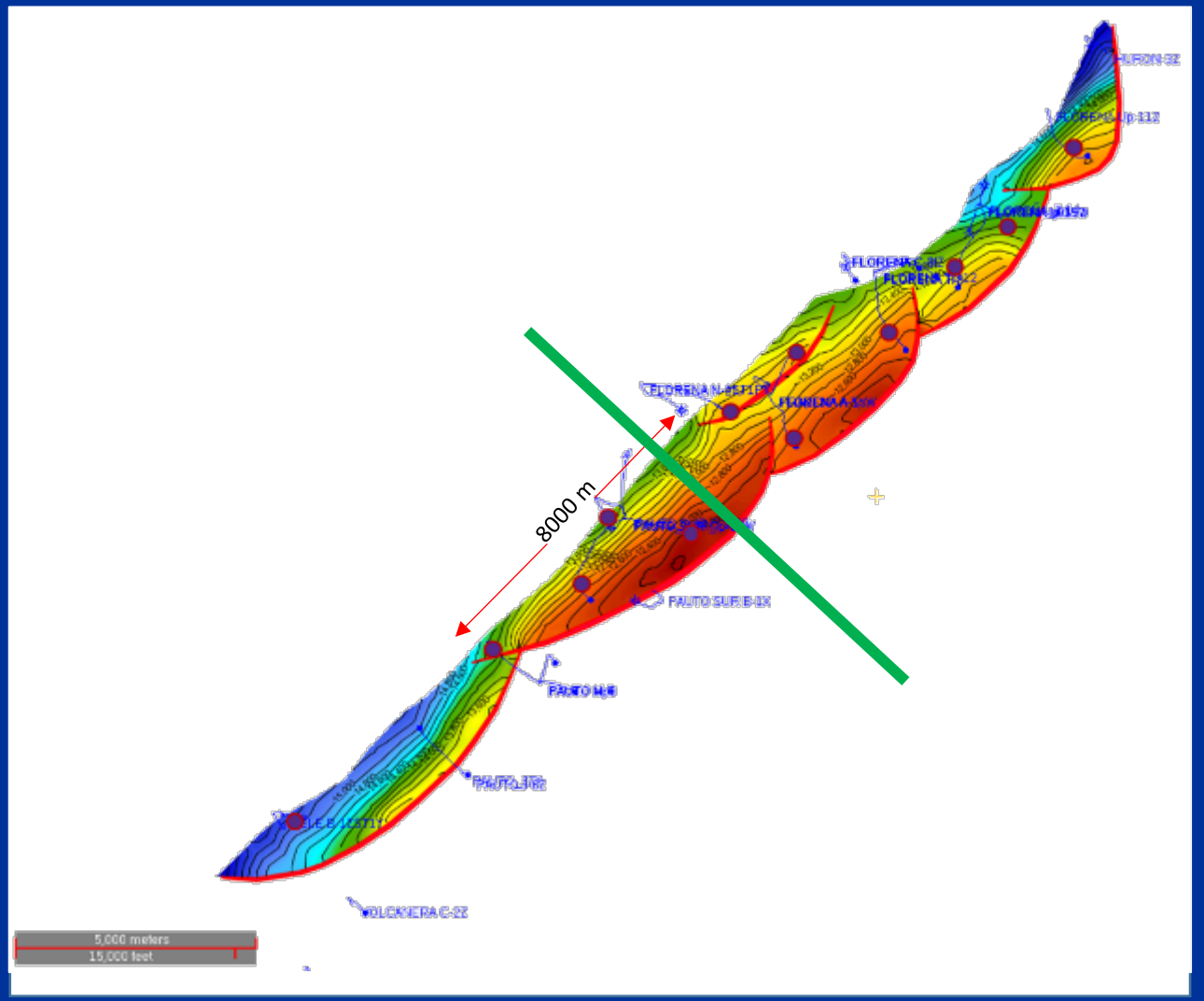
Strike seismic section

NEW INTERPRETATION



FUNDAMENTAL II



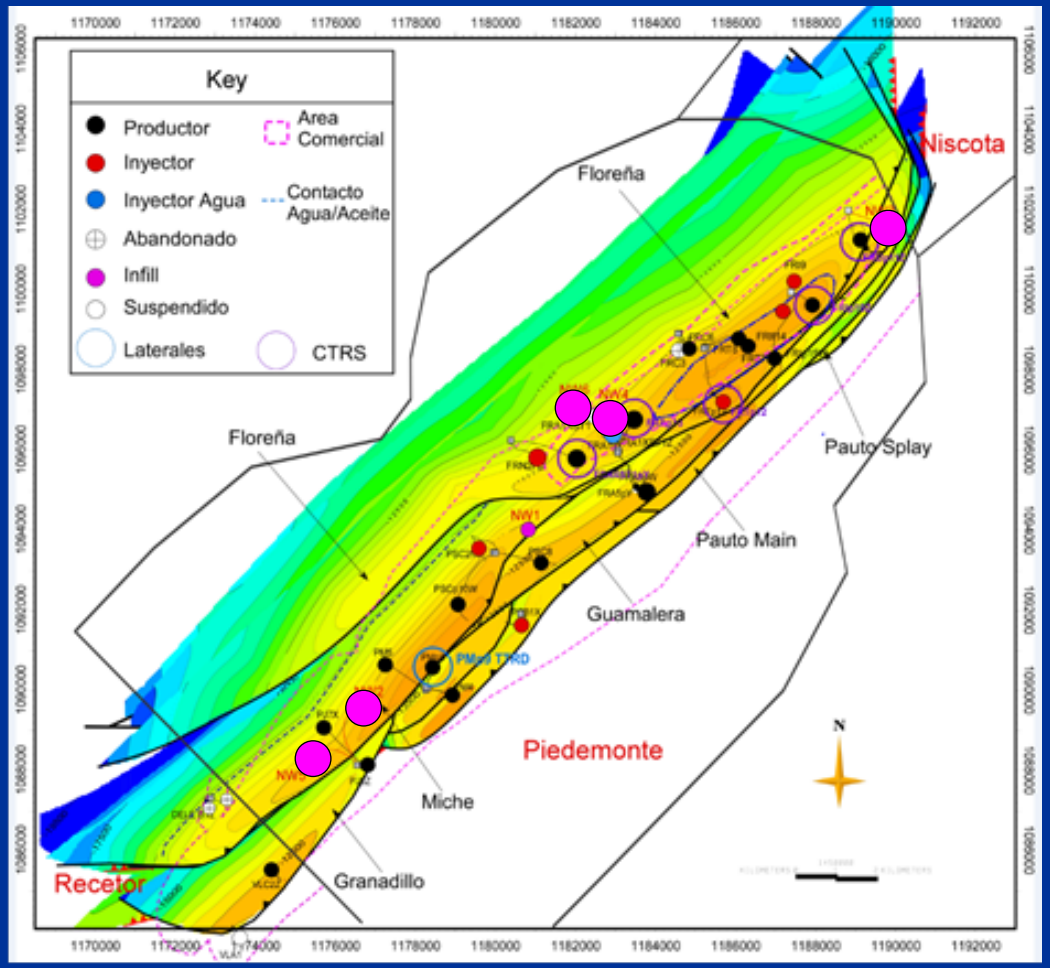


850 m are 10.6 % of the fault length

RESULTS

- Added five (5) new wells to the field development portfolio.

- Each well has a potential IOR of 4000 BOPD

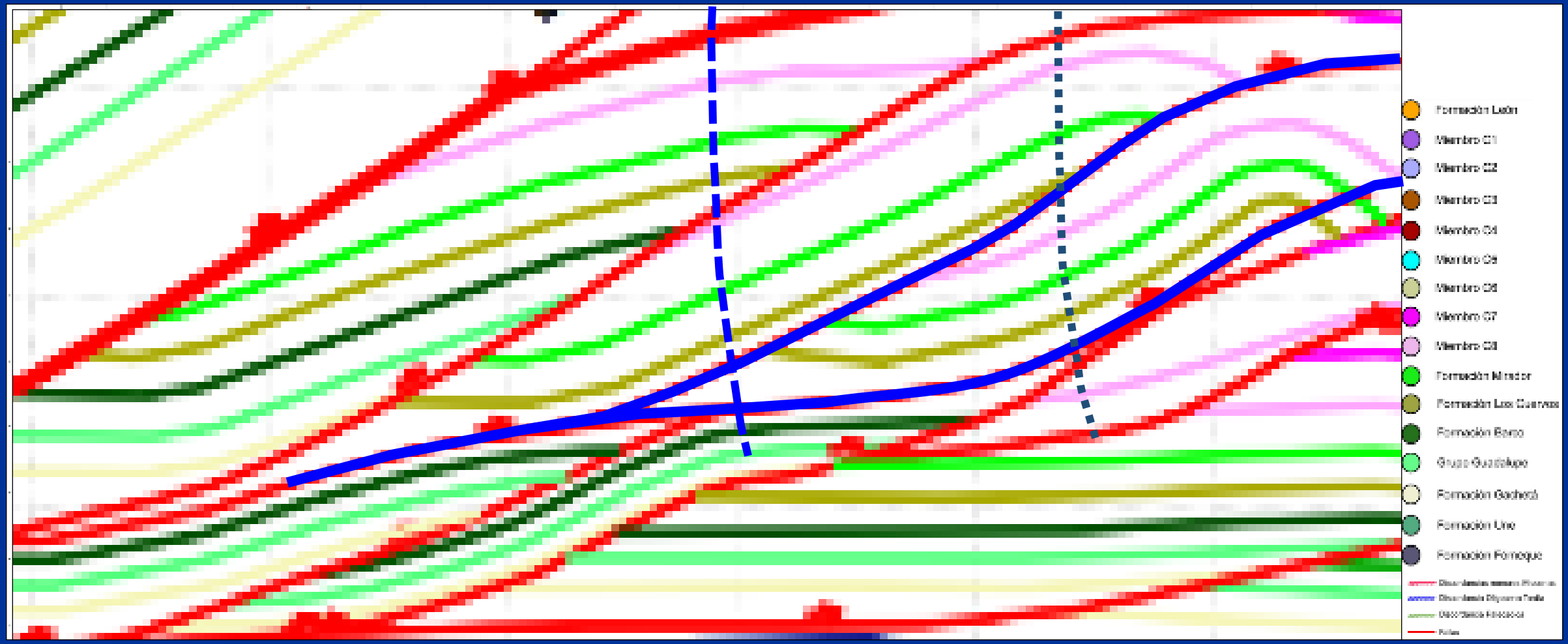


FUNDAMENTAL III

FUNDAMENTAL III

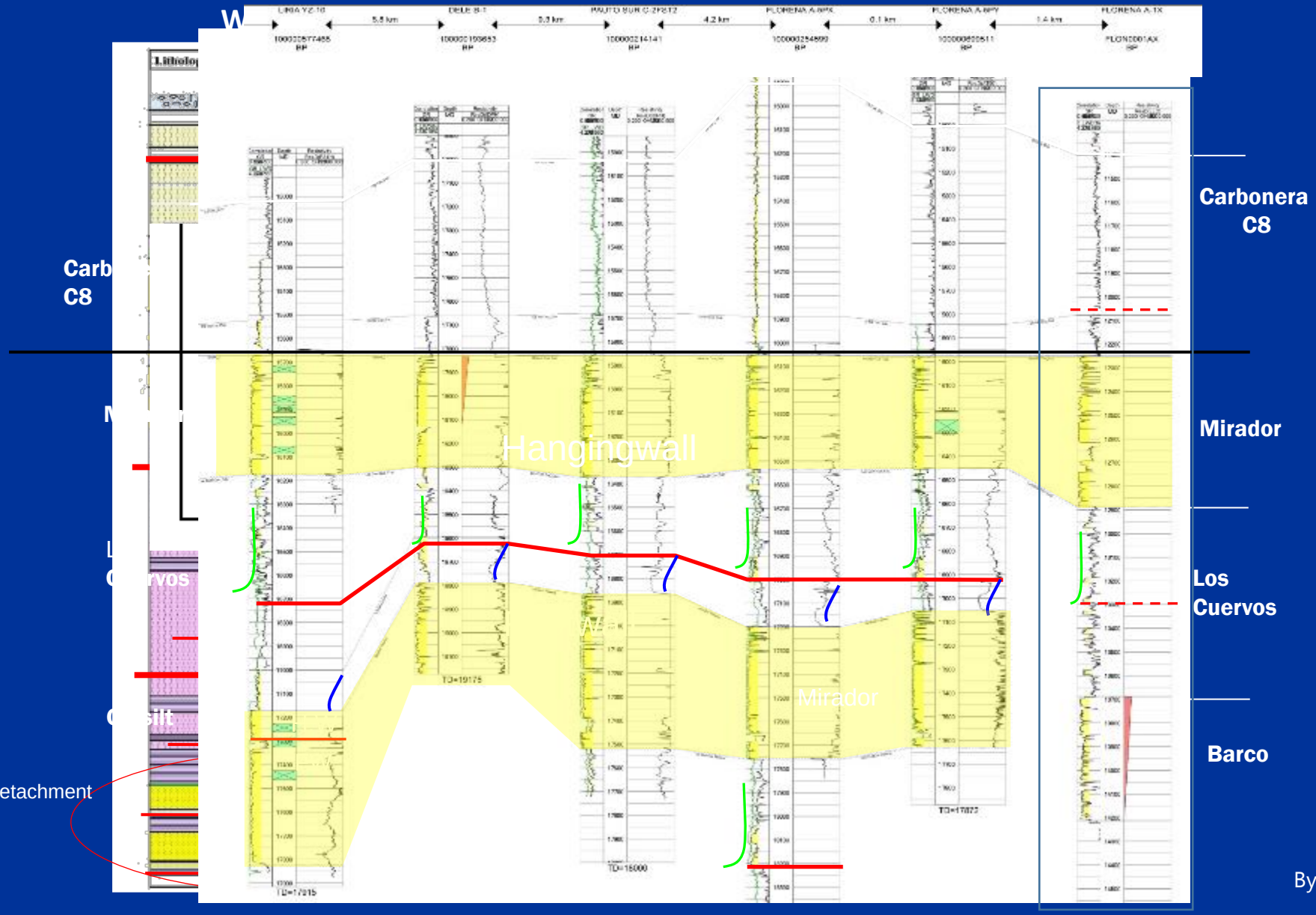
Stratigraphic depth of the detachment

For a series of thrust faults (*in sequence*) the stratigraphic level of their detachment is the same.



FUNDAMENTAL III

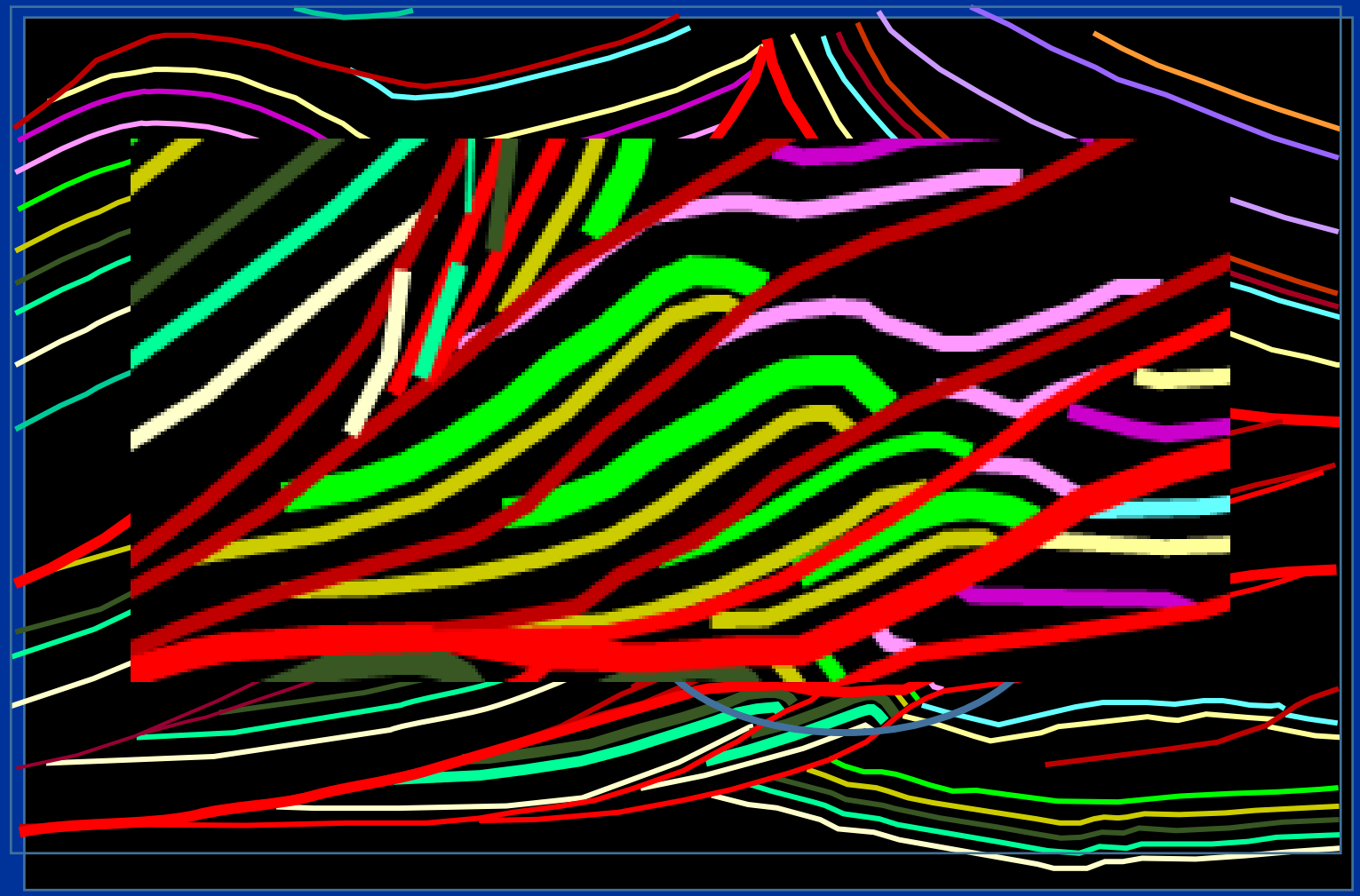
Fm. Los Cuervos detachment



By. Repsol, Byron Veilleux

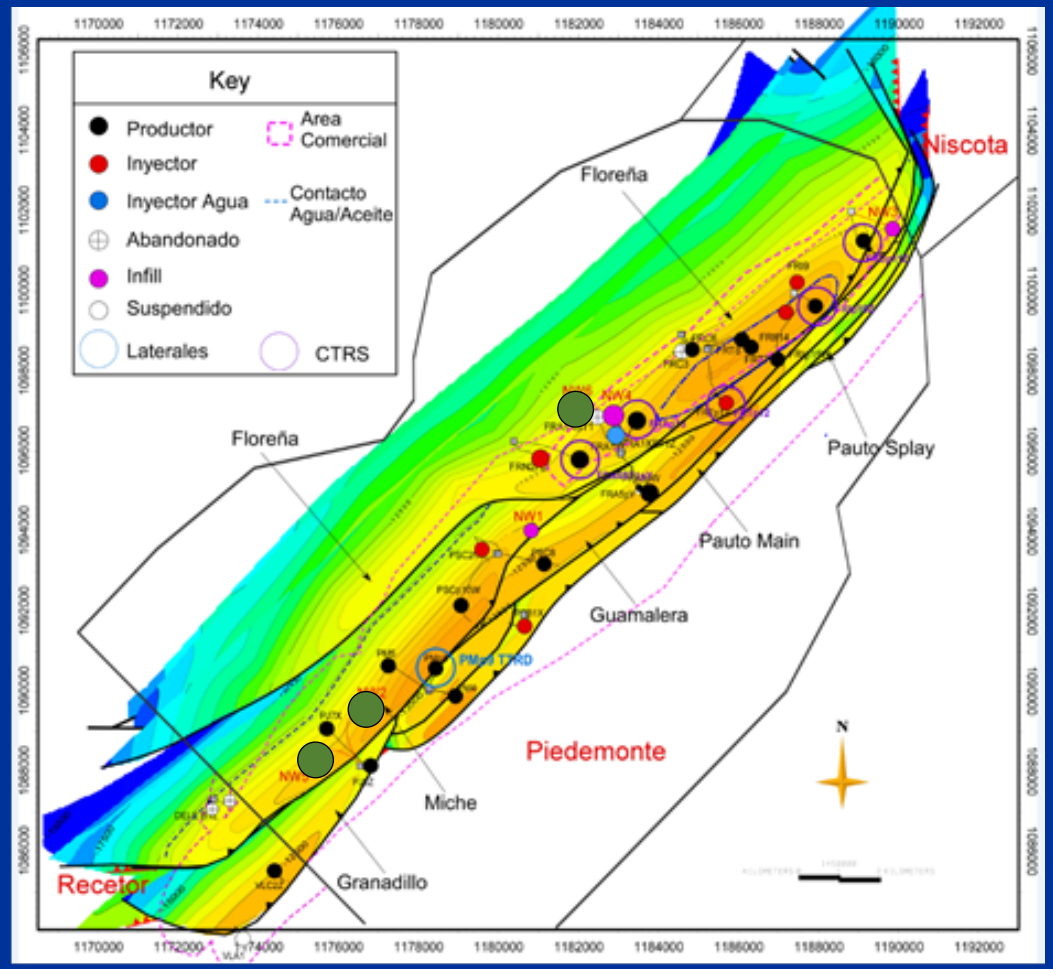
FUNDAMENTAL III

Piedemonte Model



RESULTS

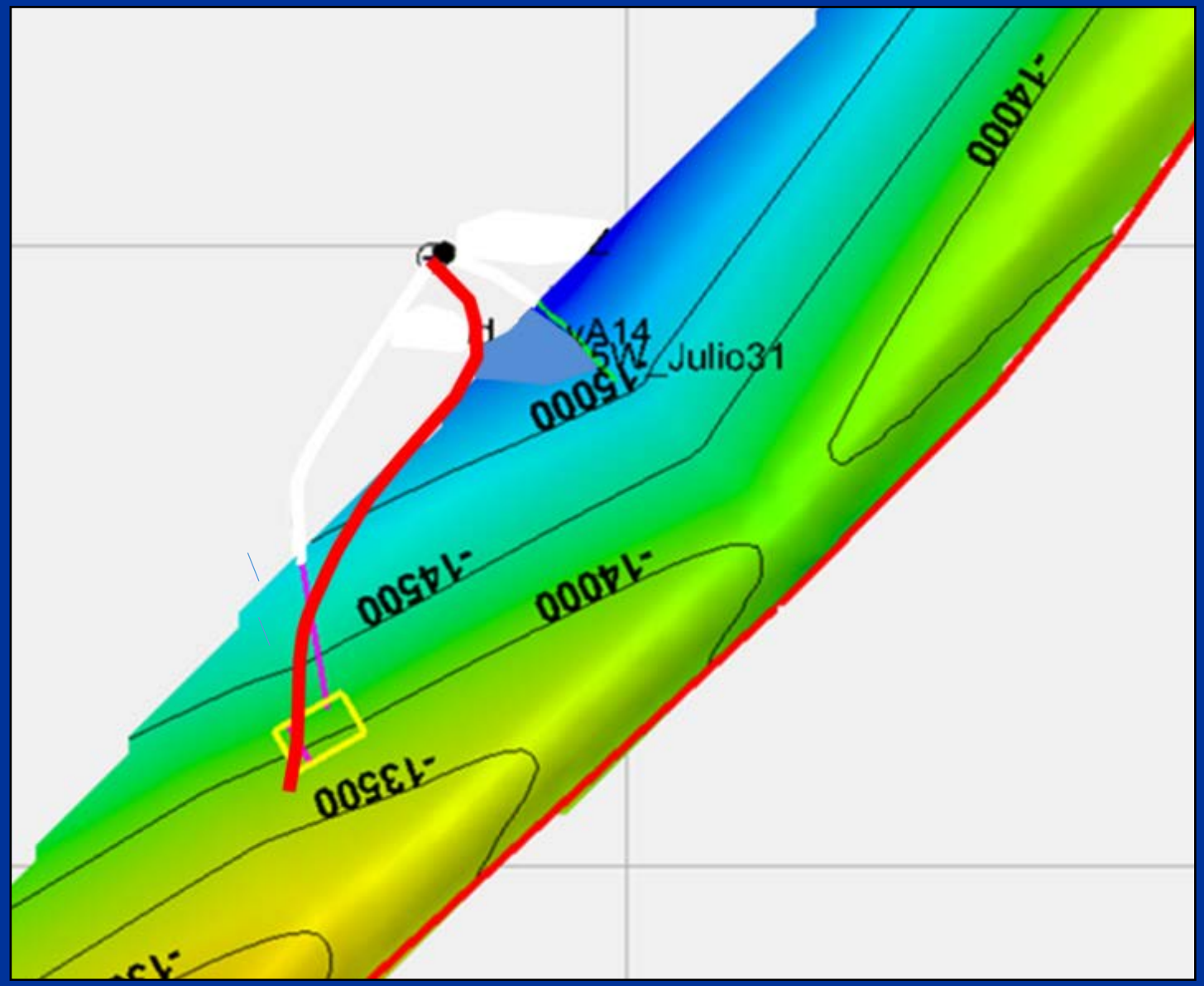
- Added three new Wells to Barco and Guadalupe reservoirs
- The potential IOR of each well is 6500 BOPD
- Explained the intermittent appearance of the Barco Fm. in the tectonic wedge in the wells.



FUNDAMENTAL IV

FUNDAMENTAL IV

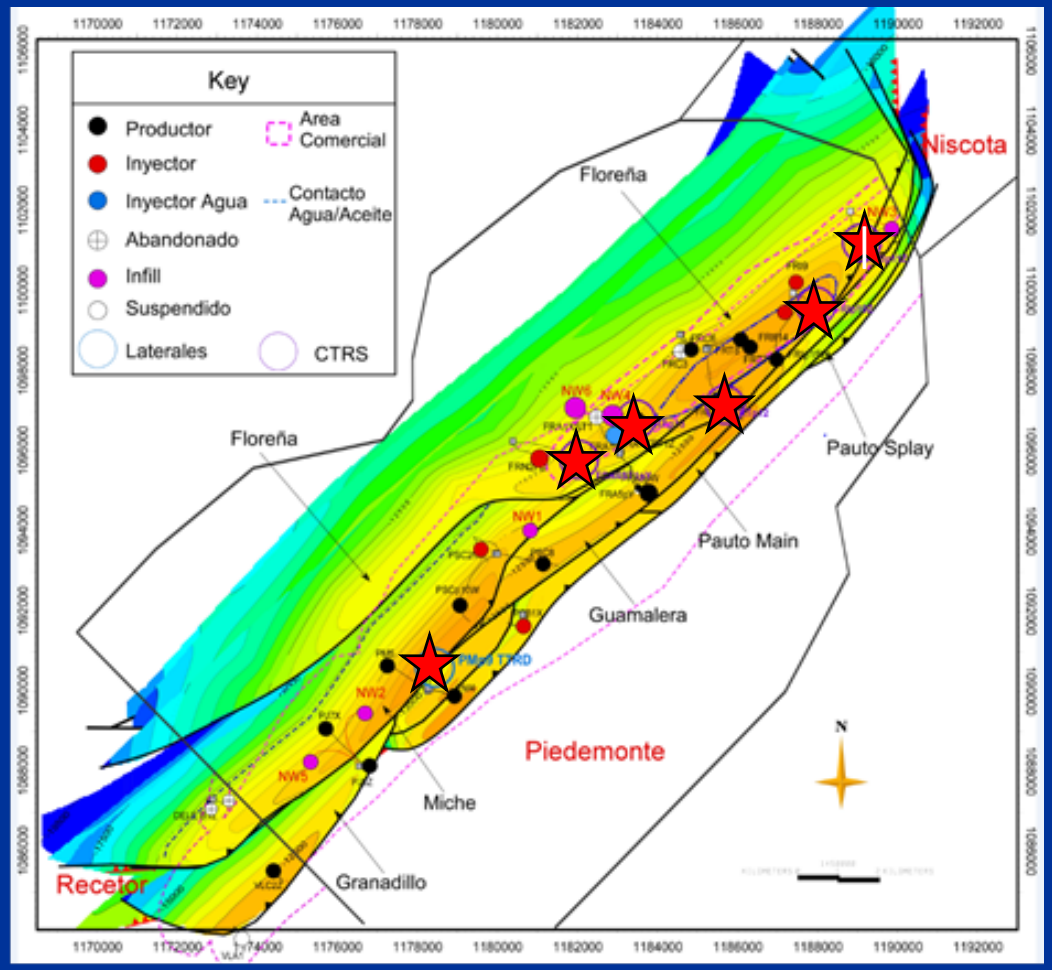
In a compressive stresses field, knowing the direction of the maximum stress, we can infer the direction of the open fractures and the sets of conjugate fractures



RESULTS

- FR15 well has an additional recoverable volume up to 6 MM STB from Mirador reservoir

- Added six lateral well to portfolio in order to drill horizontally the Mirador and Barco reservoirs

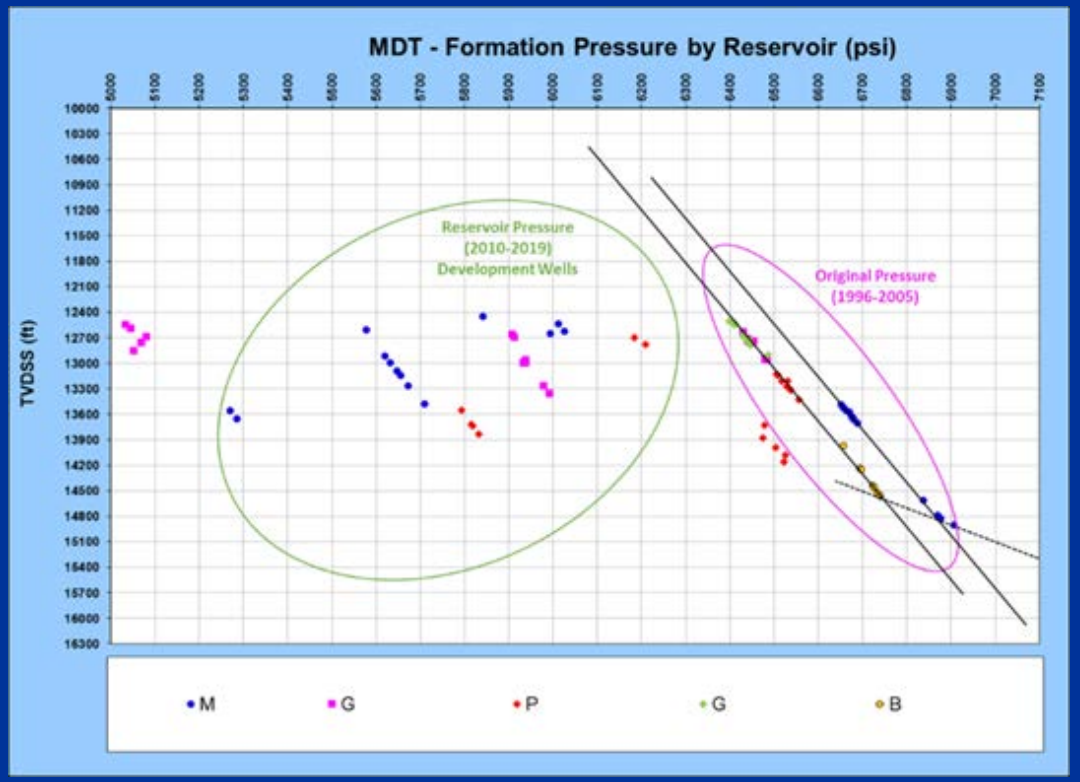


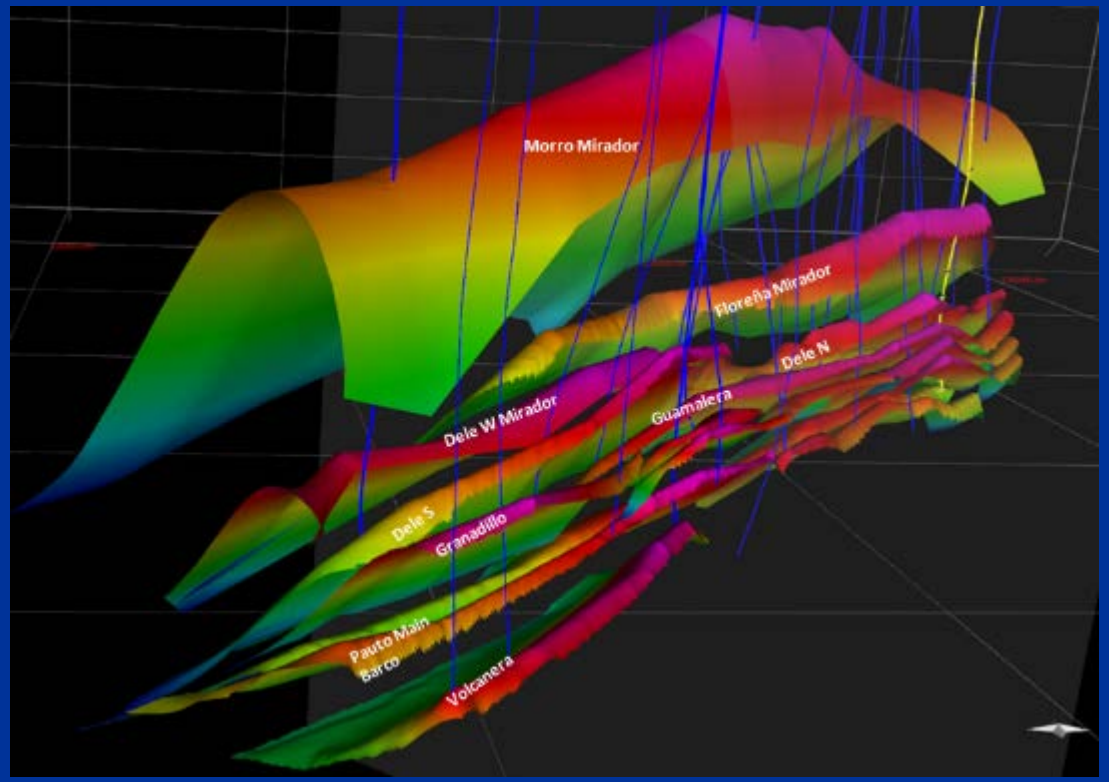
FUNDAMENTAL V

FUNDAMENTAL V

Reservoir pressure

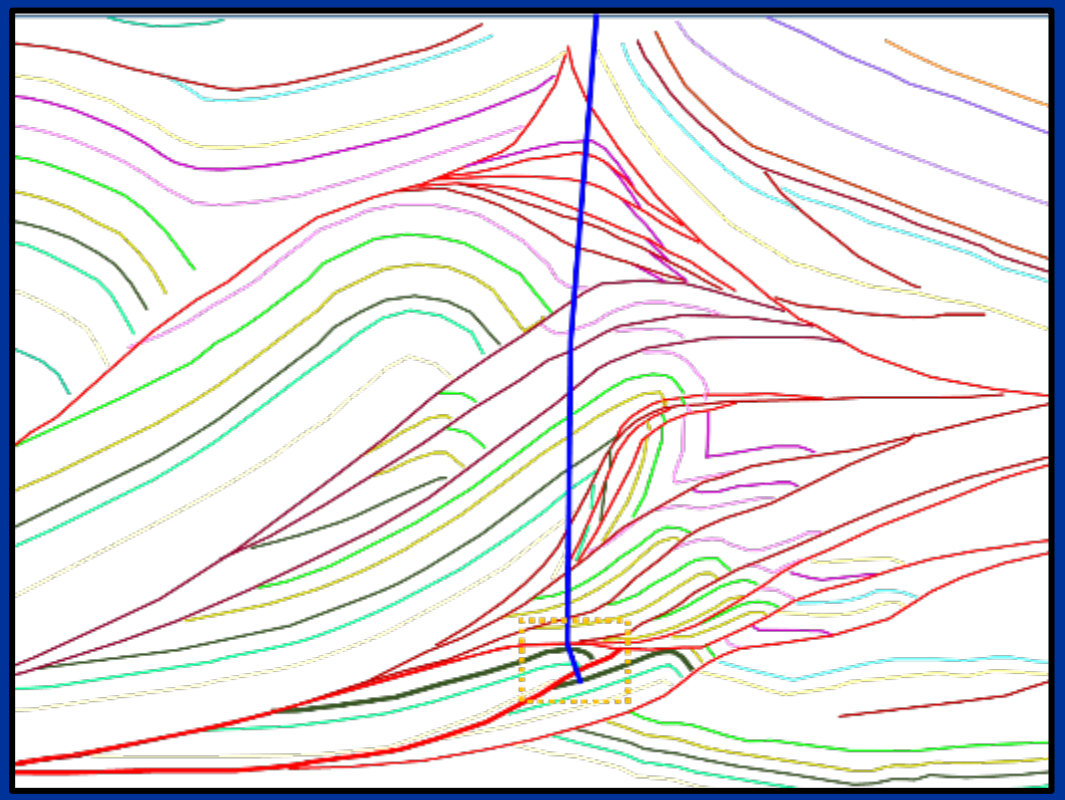
Each thrust sheet of the tectonic wedge is an independent compartment therefore has its own fluid pressure

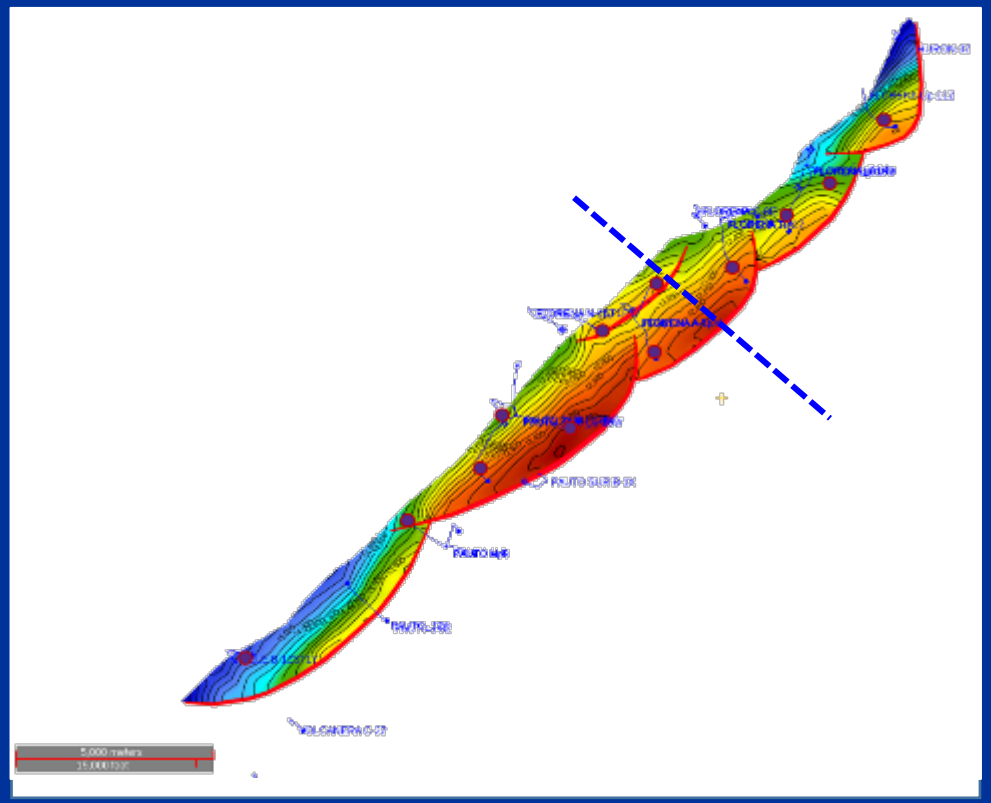




RESULTS

- Help to test the quality of the interpreted structural model
- Added at least five wells and six horizontal well to the portfolio
- Help to get a better understanding of the gas injection efficiency





MAIN CONCLUSIONS

- This methodology led to increase the value of the hydrocarbon in place in a range of 50 - 150 MMstb
- The understanding of the structural complexity of the Area allowed to create a portfolio of new development wells.

Usually, …… we find oil in new places with old ideas.

Sometimes, …….we find oil in an old place with a new idea, but

Seldom, …… we find much oil in an old place with an old idea

Parke A. Dickey

The authors gratefully acknowledge Equion Energía for providing the seismic and well data to this study, and allowing us publishing their interpretation

equion

Energía para la vida