

COLOMBIA ROUND 2021



Uptc
Universidad Pedagógica y
Tecnológica de Colombia

Petroleum System Evaluation Cauca-Patía Basin

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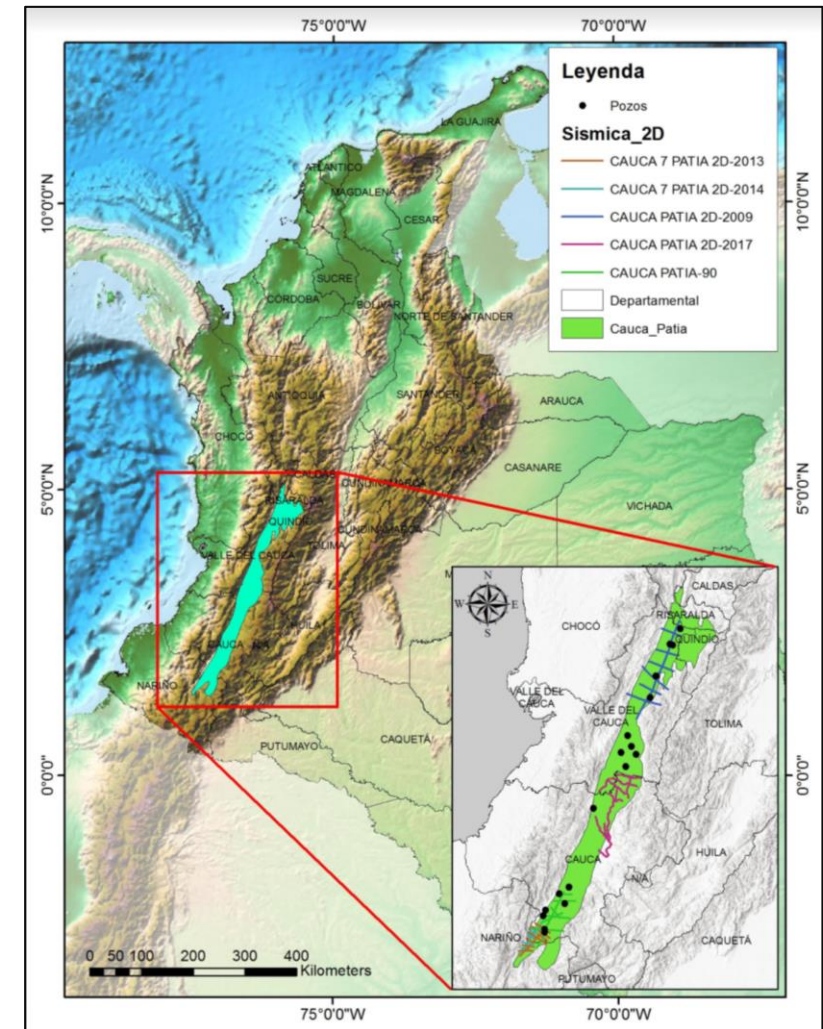
For:

Agencia Nacional de Hidrocarburos ANH

PRESENTATION OUTLINE

3

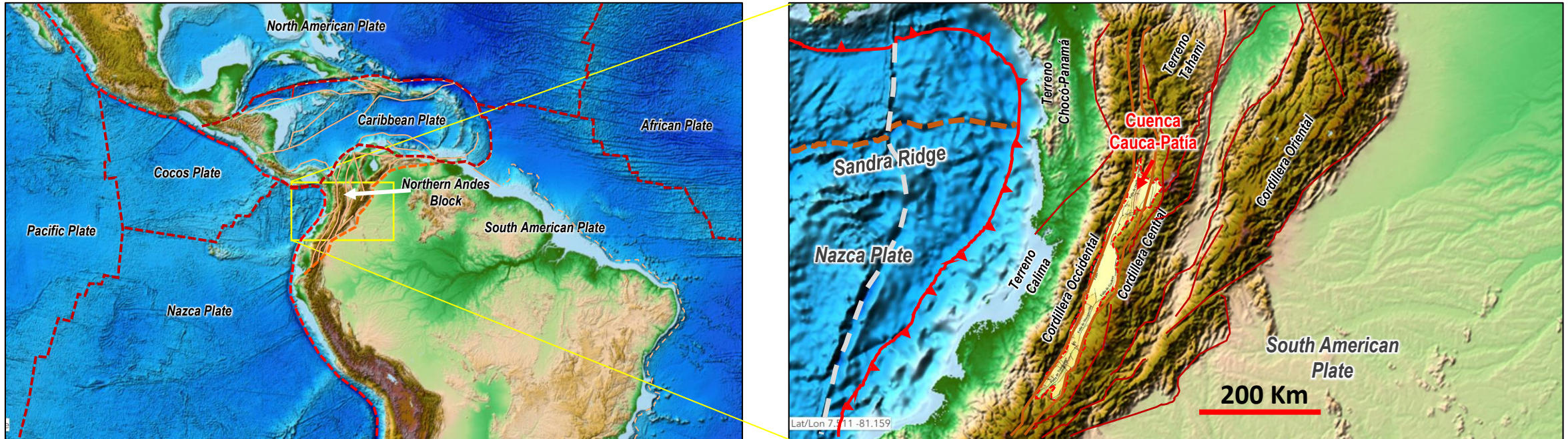
- Regional Geological Framework
- Exploration History and Database
- Chronostratigraphic Charts
- Paleogeographic Maps
- Petrography of Reservoirs and Seals
- Seismic Interpretation
- Structural Models
- Modeling of Petroleum Systems and Play Fairways
- Summary and Recommendations



REGIONAL GEOLOGICAL FRAMEWORK

4

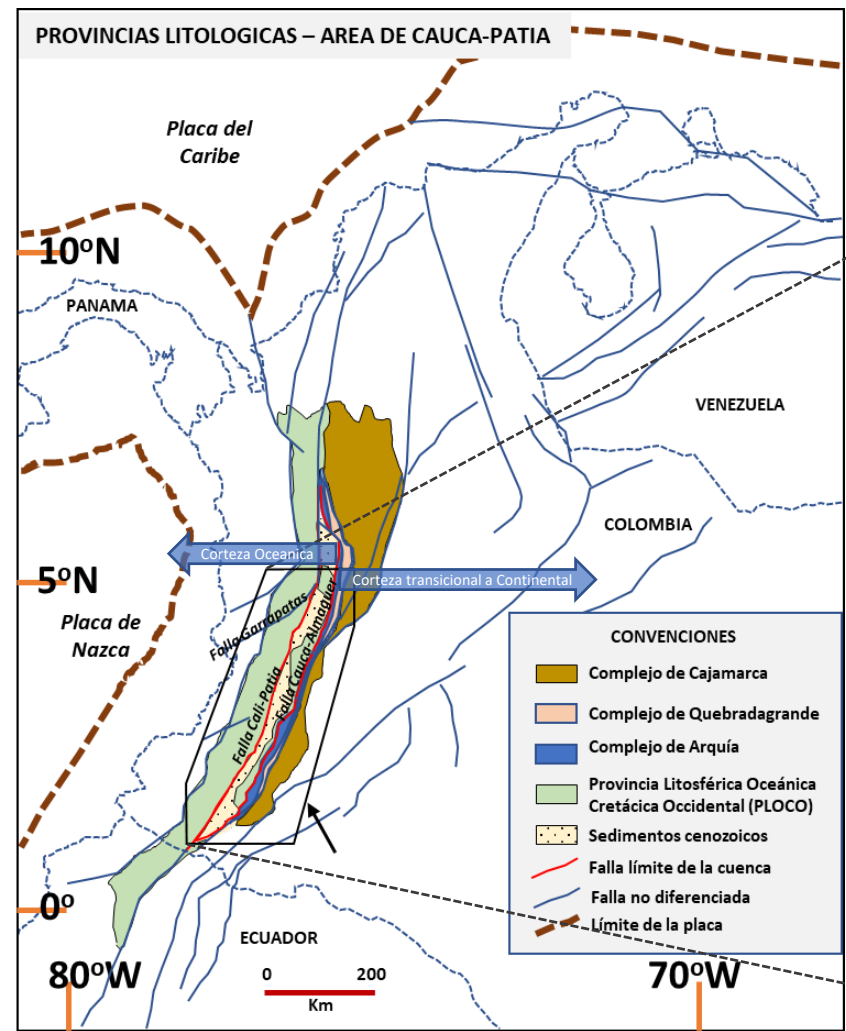
The Cauca-Patía basin experienced multiple tectonic events and displays a high structural complexity



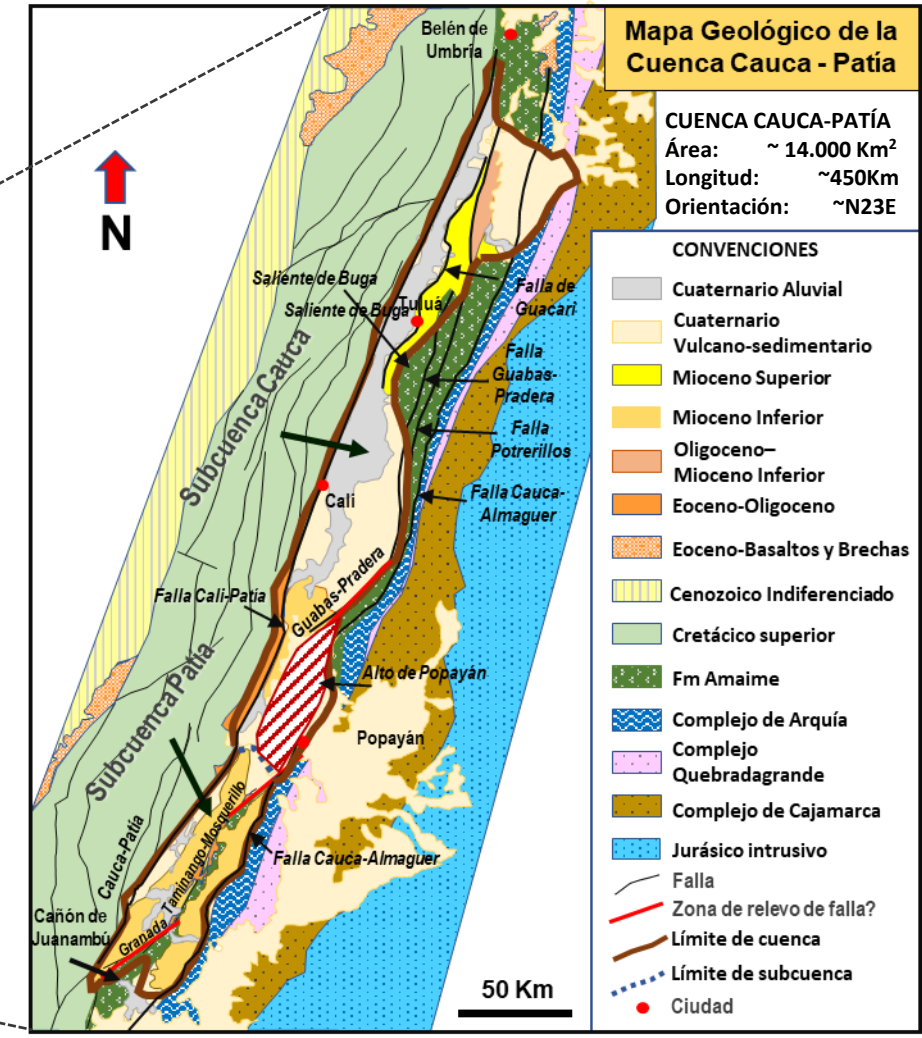
- ❖ The Cauca-Patía Basin is located in the Northern Block of the Andes, between the Central and Western mountain ranges of Colombia
- ❖ It is a poly-history tectonic basin of multiple phases that originated with the separation of the North and South American plates during the Middle Jurassic and the subsequent interaction with the Proto-Caribbean, Caribbean and Nazca plates
- ❖ The initial sedimentation, dominantly marine, corresponds to a passive margin basin in the Lower Cretaceous and active during the Late Cretaceous. It is followed by a predominantly forearc sedimentation setting during the Paleogene to the Middle Miocene and then Intermontane from the Late Miocene to the present time
- ❖ The basin experienced sporadic uplifts during the Tertiary, associated with the subduction of the Nazca plate under the South American plate and the emplacement of the Chocó-Panamá Terrain

GEOLOGY AREA CUENCA CAUCA-PATÍA

Continental margin lithological provinces along the boundary between continental and oceanic crusts



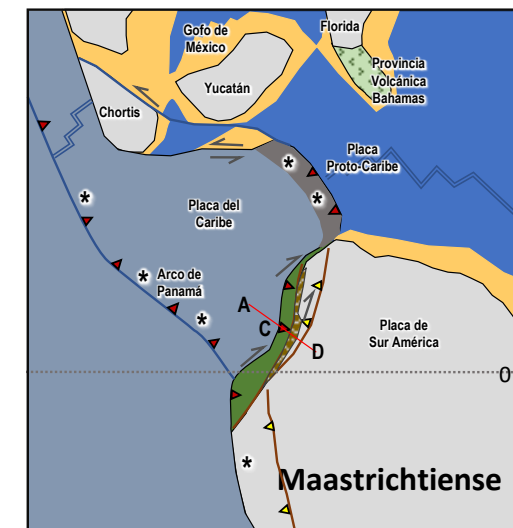
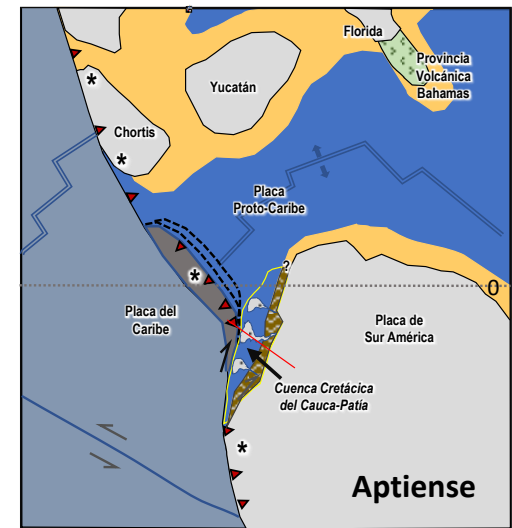
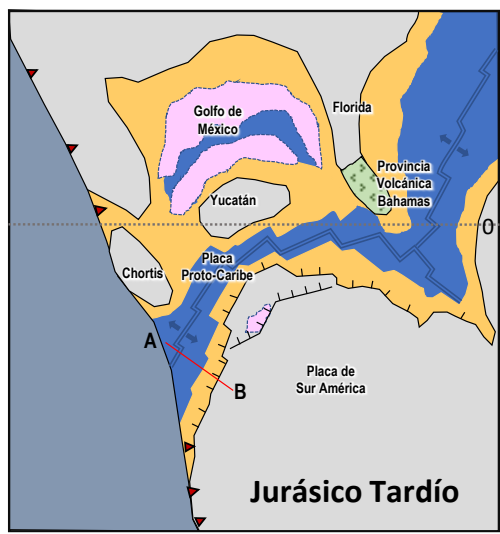
Tomado y modificado de Nivia et al (2006).



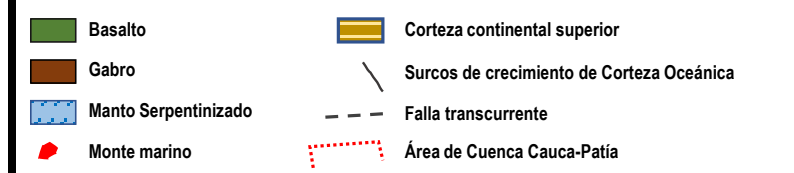
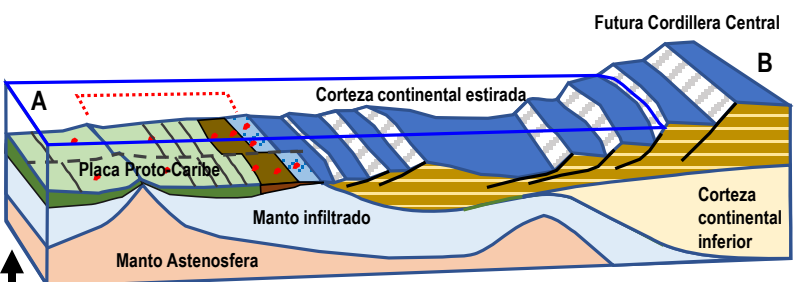
Tomado y modificado Mapa Geol. de Colombia. Escala 1:500.000, Gómez, et al. (2015)

CAUCA-PATÍA TECTONIC EVOLUTION

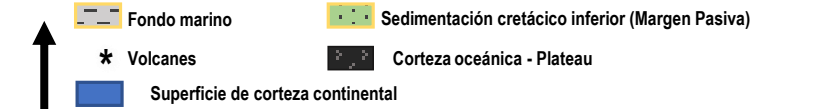
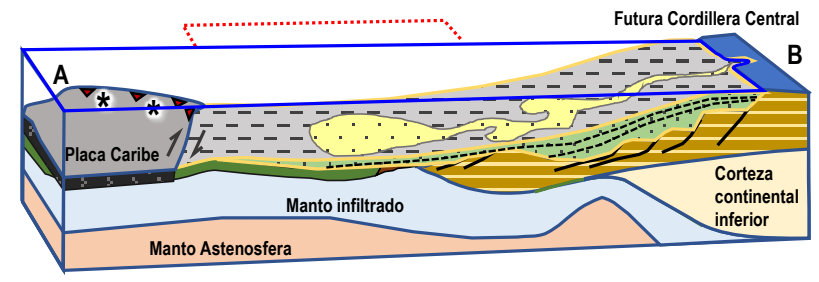
Passive margin during extension phase to an active one during the Aptian transpression



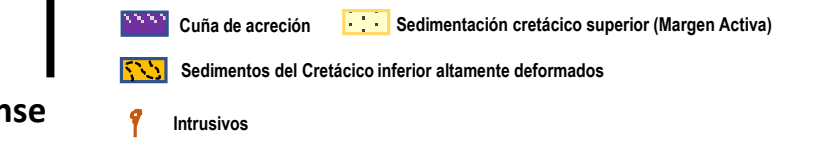
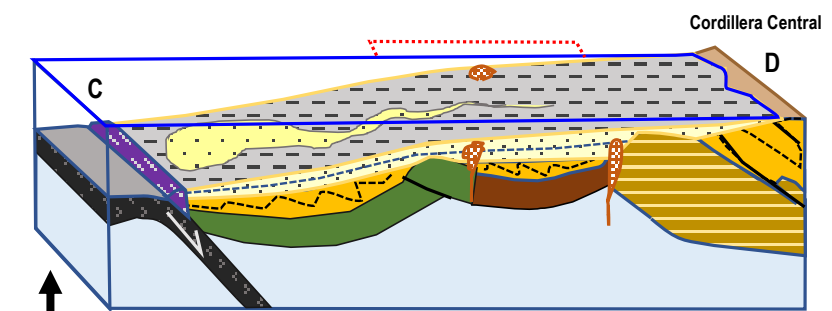
Note: Source of the maps on the next slide



Late Jurassic



Aptiense Pre-accretion

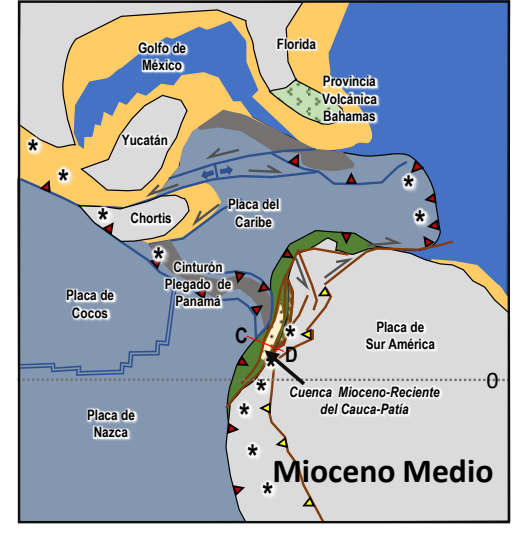
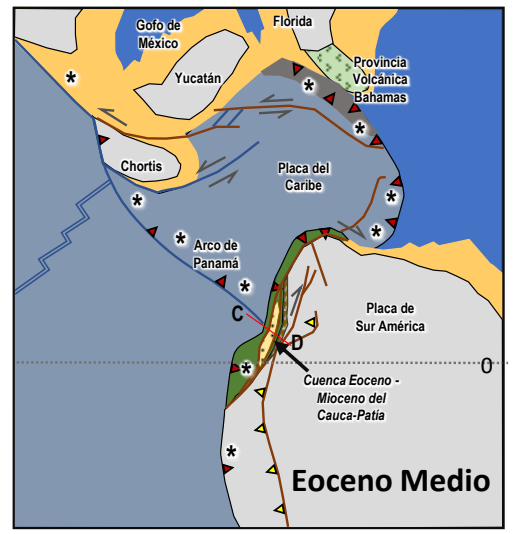
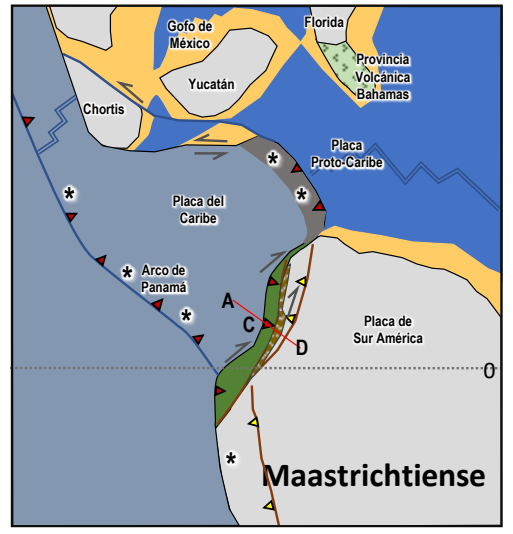


Maastrichtiense Pre-accretion

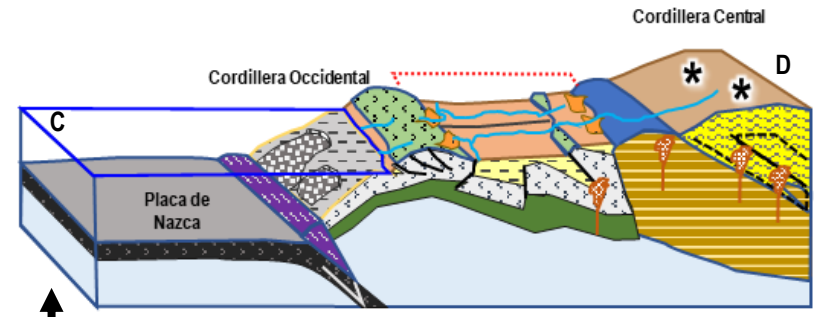
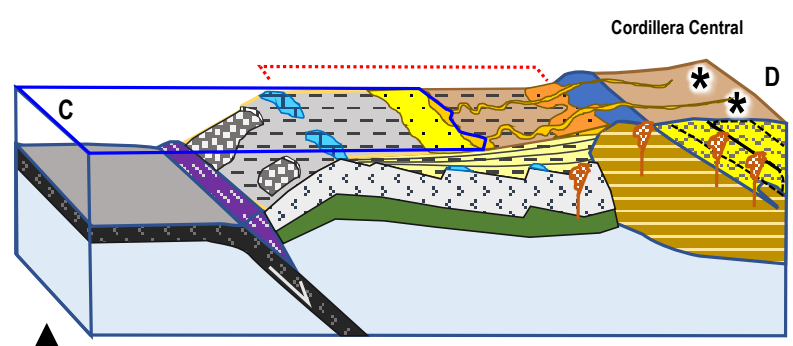
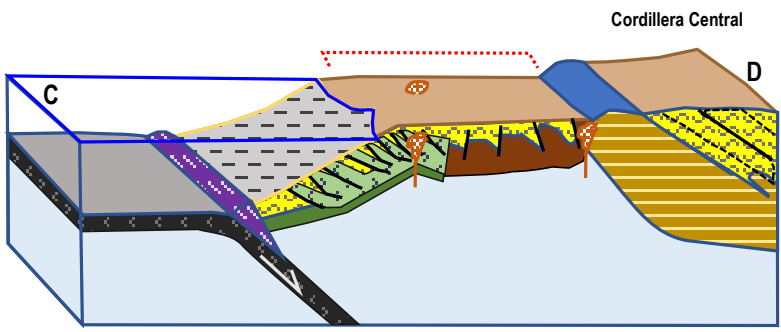
Note: Hypothetical model diagrams drawn not at scale

CAUCA-PATÍA TECTONIC EVOLUTION

Subduction in the Late Cretaceous, fore arc in the Paleogene and intermontane in the Late Miocene



Illustrative diagrams of the tectonic development of the NW of South America and the Caribbean based on models of kinematic evolution of the Gulf of Mexico and the Caribbean (Pindell and Keenan, 2001) and paleomap reconstructions (Scotese 2001)



- Corteza oceánica delaminada e imbricada
- Sedimentos del cretácico altamente deformados
- Cuña de acreción
- Intrusivos

Maastrichtian Post - accretion

- Abanico aluvial
- Llanura costera
- Playa, línea costera
- Mezcla de sedimentos del cretácico y corteza oceánica imbricada
- Carbonatos
- Transporte en masa
- Sedimentos Eoceno a Mioceno
- Aluvial a deltaico

Paleogene

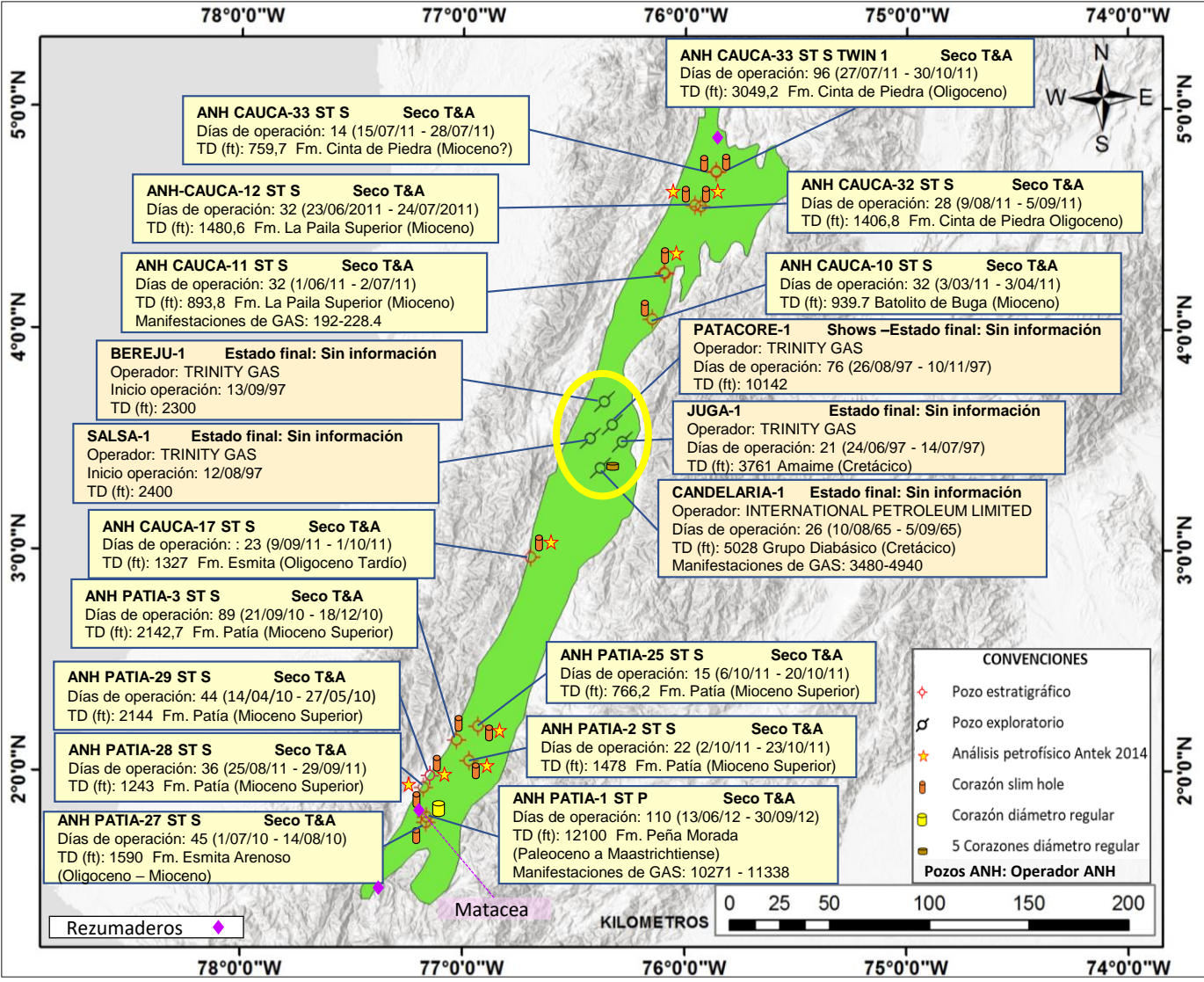
- Rios
- Superficie de corteza continental
- Sedimentitas cretácicas expuestas
- Mezcla de sedimentitas cretácicas y corteza oceánica expuestas
- Inicio de sedimentación Mioceno Tardío

Late Miocene to Quaternary

Note: Hypothetical model diagrams drawn not at scale

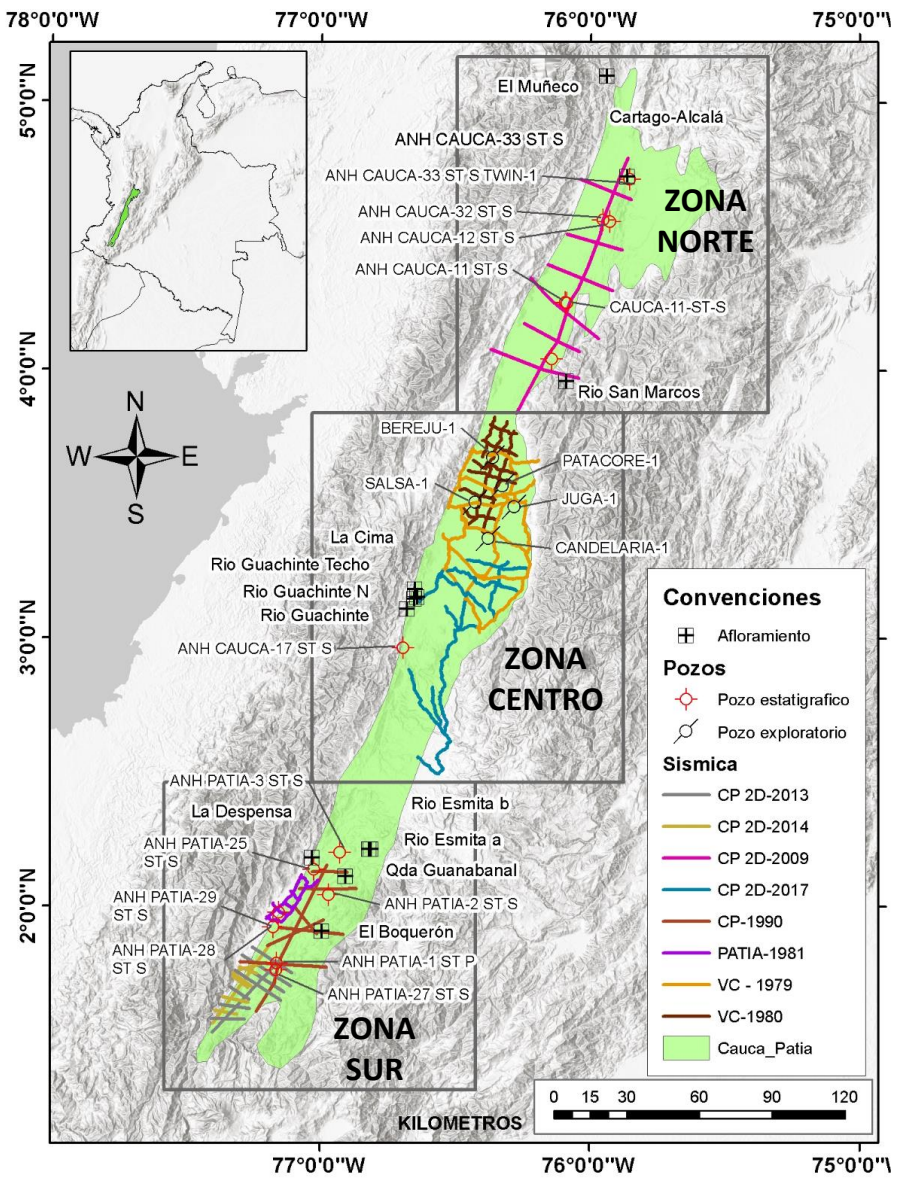
EXPLORATION HISTORY

Well status map



- 5 Exploration wells.
 - 1 in 1965 (Intern. Pet. Co.) 5 cores
 - 4 in 1997 (Trinity Gas Co.) Without Final Geological Report
- 14 cored Stratigraphic Wells ANH - 2010-2012
 - 13 shallow slim holes
 - 1 Deep hole (regular hole diameter)
- 9 Wells with lab analysis (Antek 2014 for the ANH)
 - Petrographic, petrophysical,
 - Biostratigraphy
 - Thermochronology
 - Geochemical
- 3 well with gas shows (Centro-Sur)
- All Wells in the basin are dry holes, T&A
- 3 reported oil seeps
 - Just one, Matacea, has geochemical information

GEOPHYSICAL INFORMATION AND OUTCROPS



- **8 2D seismic programs (~1861.7 Km)** in three specific zones
- North Zone
 - 2009 – ANH –UT Perforaciones 293.9 Km
- Central Zone
 - 1979 & 1980 – Ecopetrol – Western Geophysical - 683.6 Km
 - 2017 – ANH – Consorcio Eco-Ondas – 323.3 Km
- South Zone
 - 1981 – Ecopetrol – Western Geophysical – 80.2 Km
 - 1990 – Ecopetrol – Sismocol SA. 210.3 Km
 - 2013 – GranTierra – Geofísica Latinoamericana - 174.8 Km
 - 2014 – GranTierra – Energy Geophysical Services - 95.6 Km
- **3 Gravimetric and magnetometric programs (G&M)**
 - 2006 – ANH – Carson Helicopters Inc. - 4795 Km Aerial-G&M Central and North Zones
 - 2012 – ANH - Asesorías Geofísicas de Col. - 1243 stations G&M along 2009 2D seismic lines
 - 2012 – GranTierra- Sanders Geophysical – 9000 Km Aerial G&M South Zone
- **Stratigraphic sections** 9 from Geoestudios 2008 y 2 from Pardo-Trujillo et al (2002)

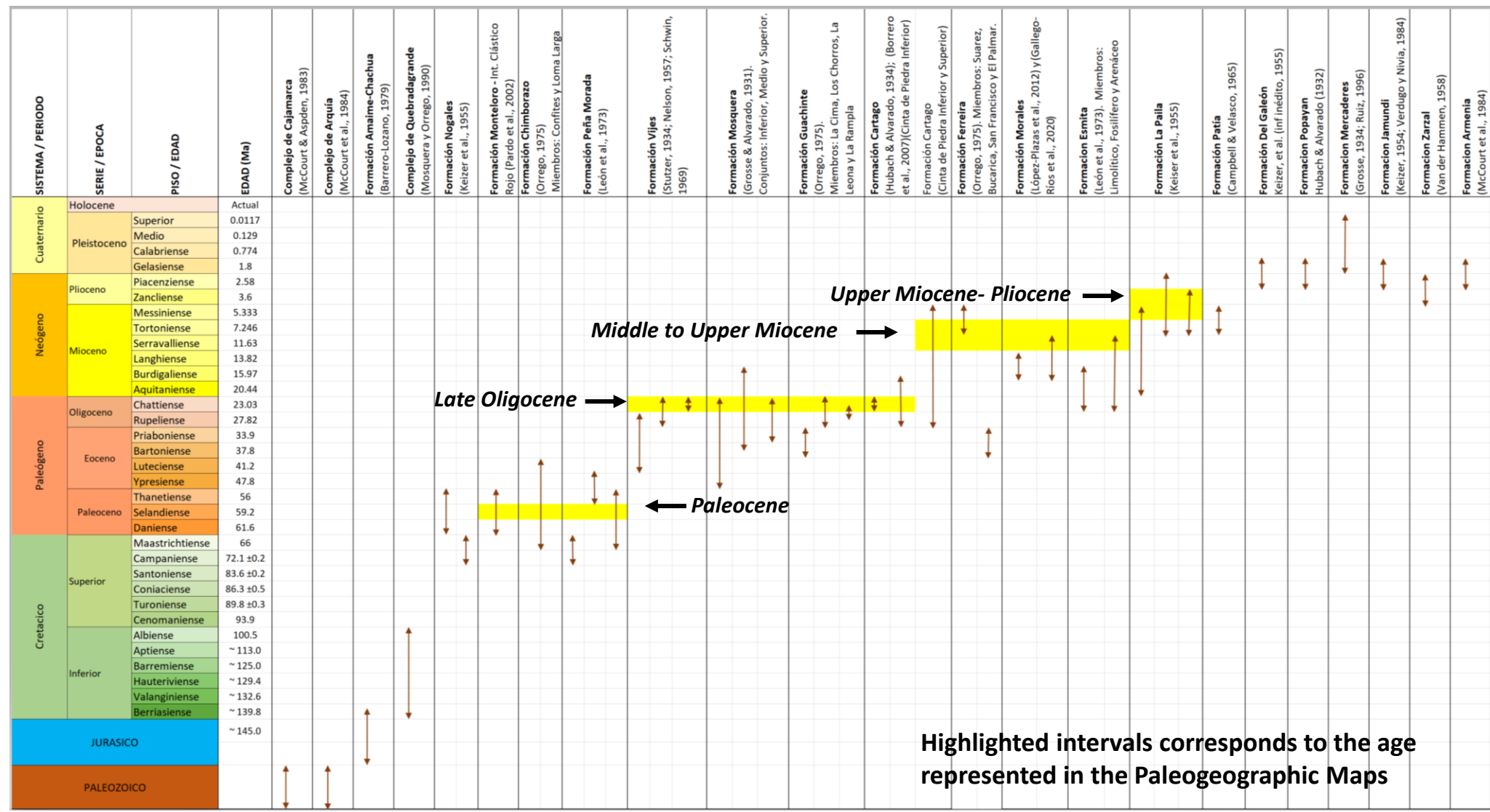
Chronostratigraphic charts

Paleogeographic Maps

Reservoirs and Seals

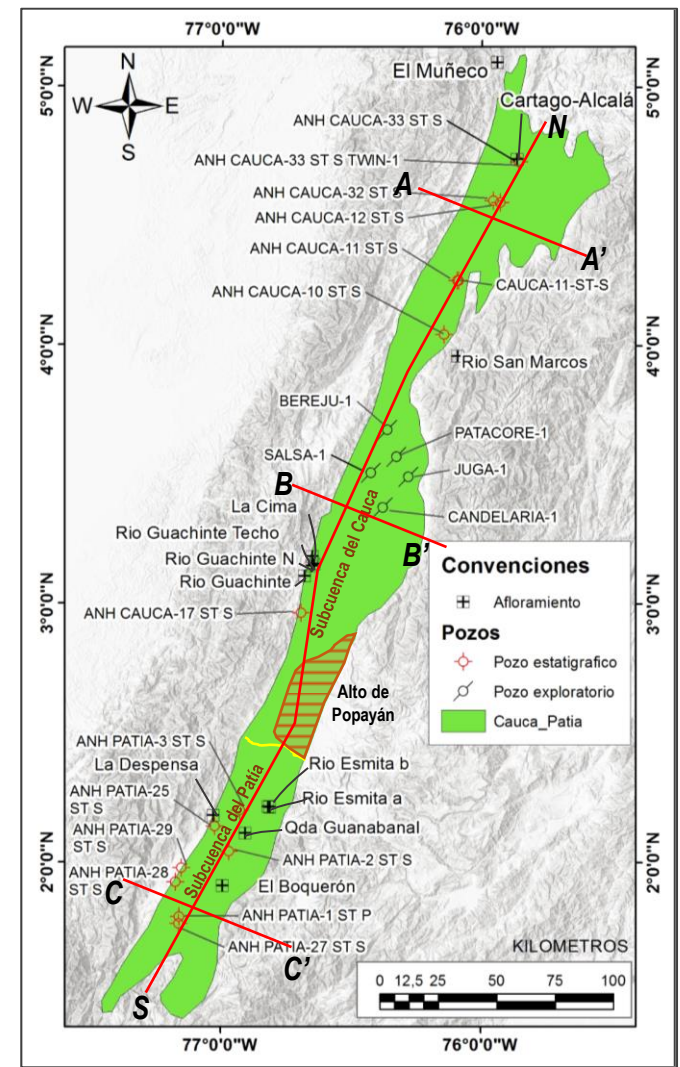
STRATIGRAPHY OF THE BASIN

Age allocation according to consulted reports



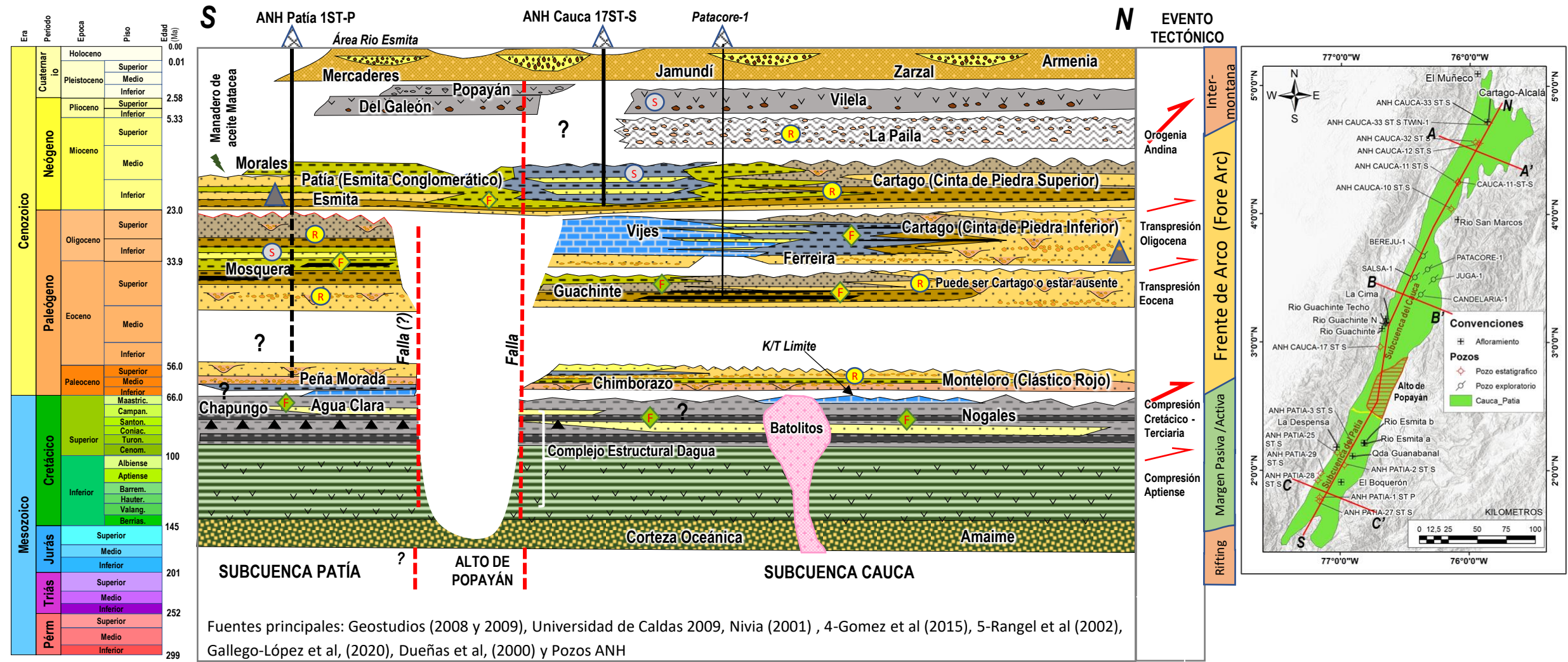
CHRONOSTRATIGRAPHY CAUCA-PATÍA

Index map of sections and Lithology legend



CHRONOSTRATIGRAPHY CAUCA-PATÍA

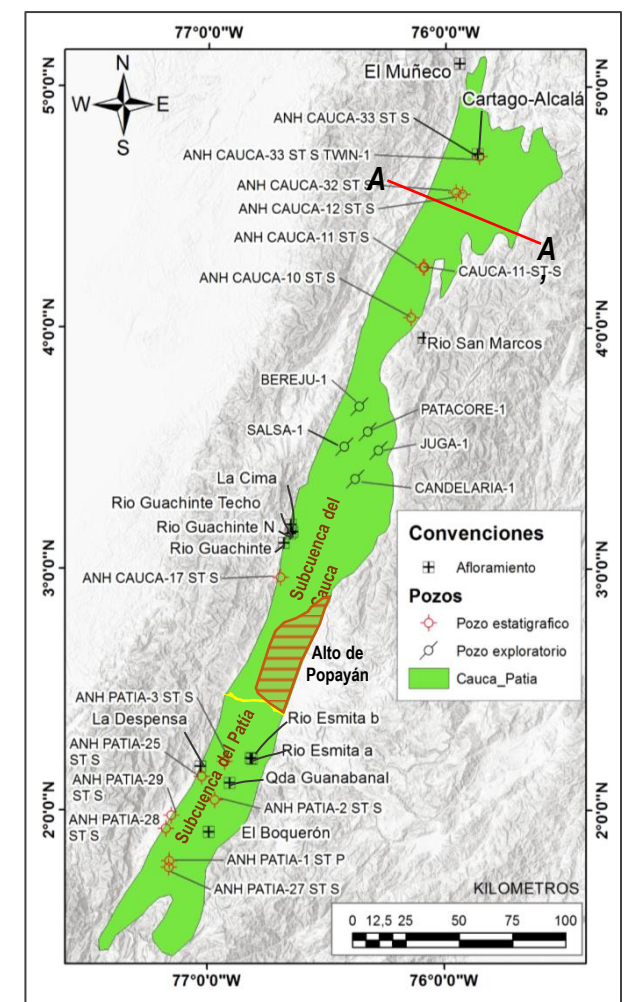
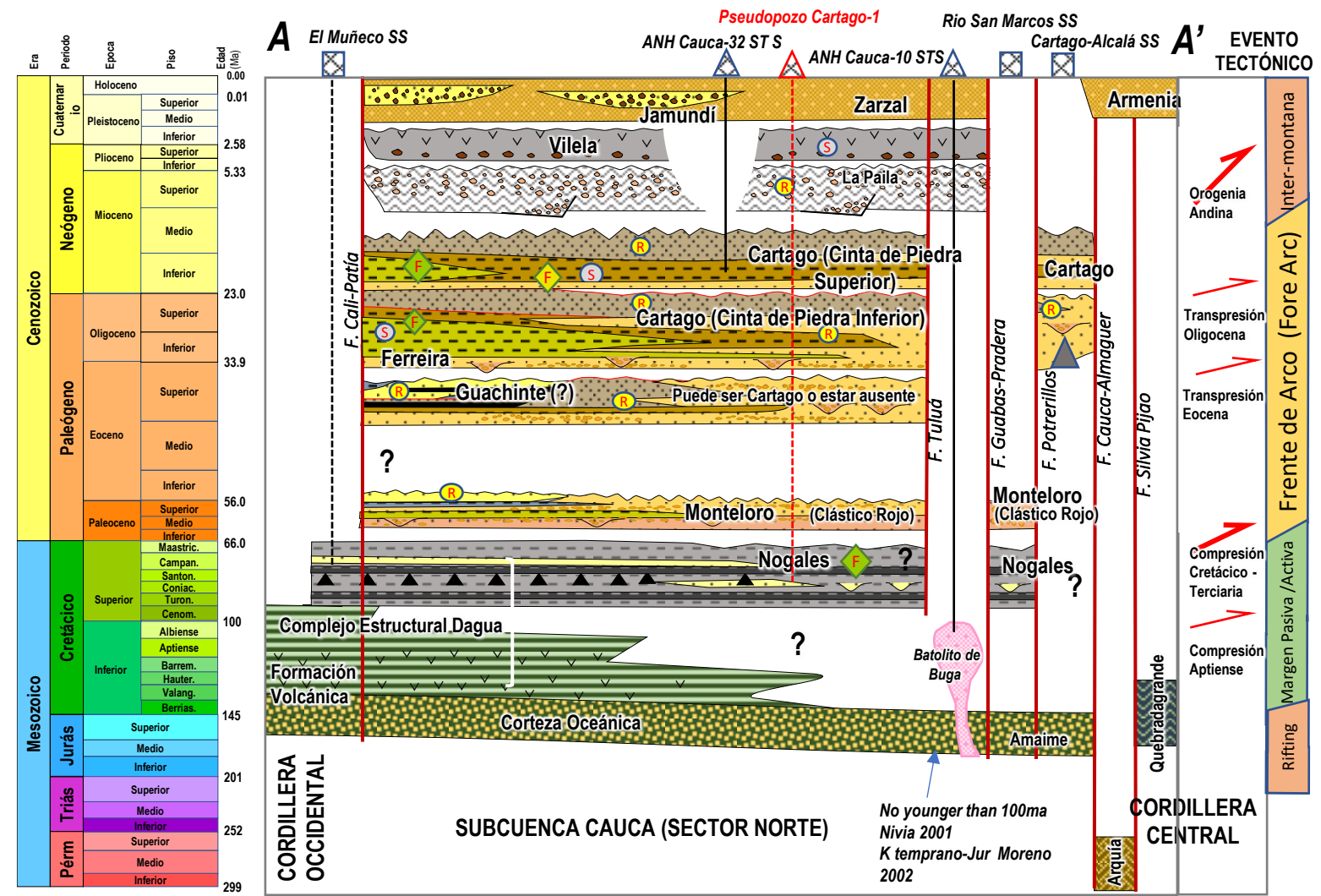
Longitudinal section S-N



Fuentes principales: Geostudios (2008 y 2009), Universidad de Caldas 2009, Nivia (2001), 4-Gomez et al (2015), 5-Rangel et al (2002), Gallego-López et al, (2020), Dueñas et al, (2000) y Pozos ANH

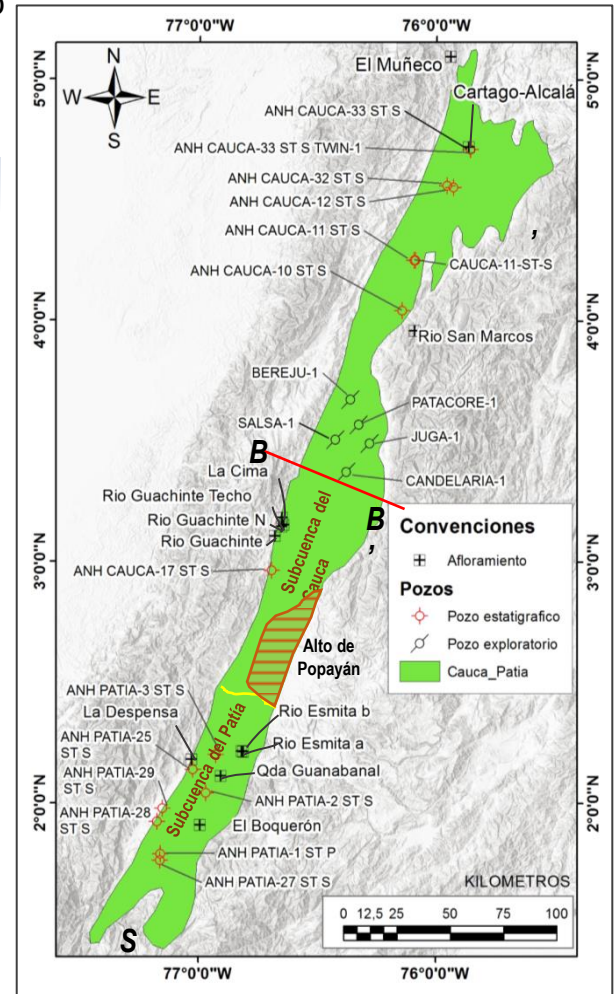
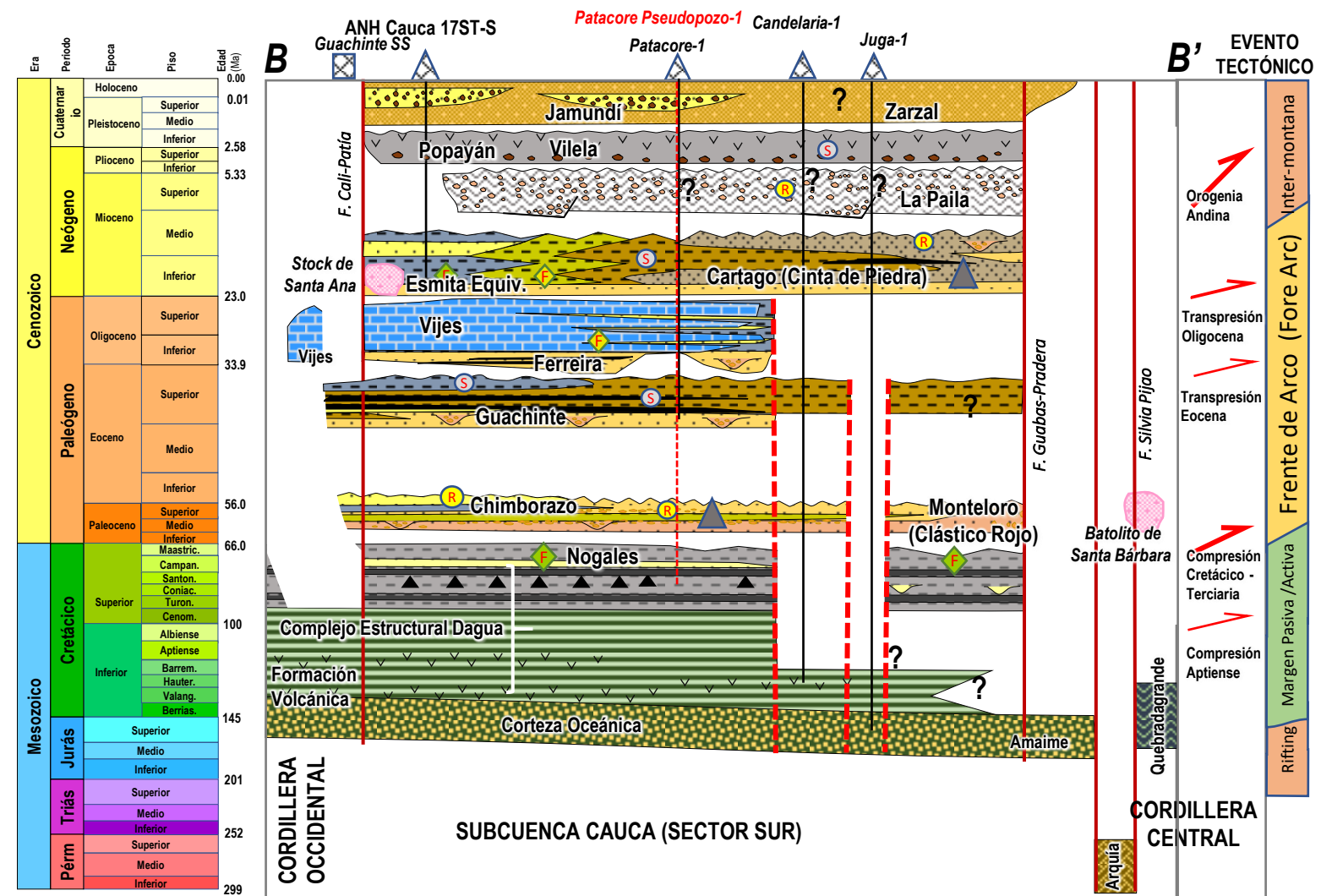
CHRONOSTRATIGRAPHY CAUCA-PATÍA

Cross Section A-A'



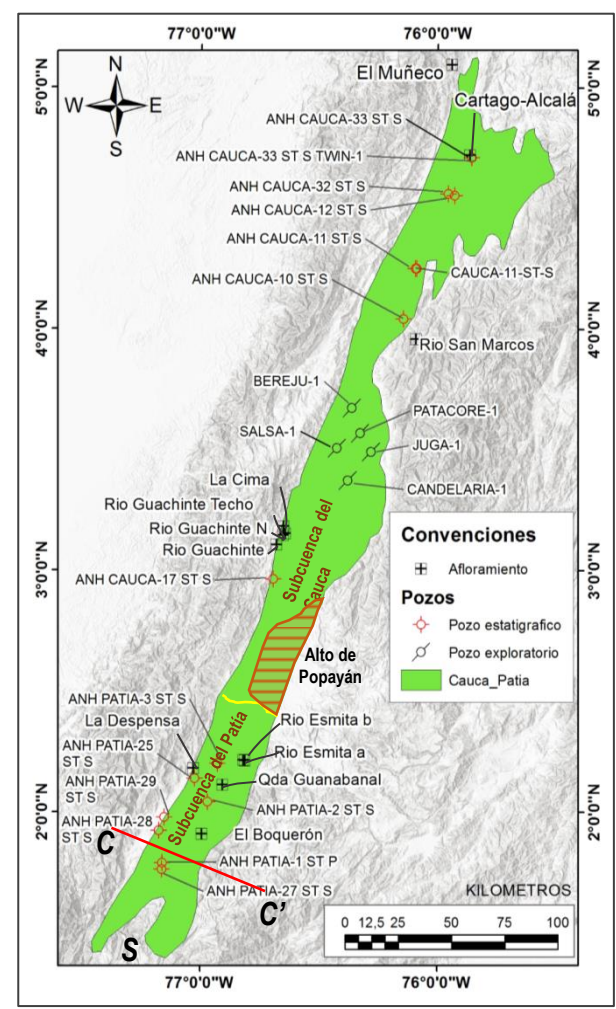
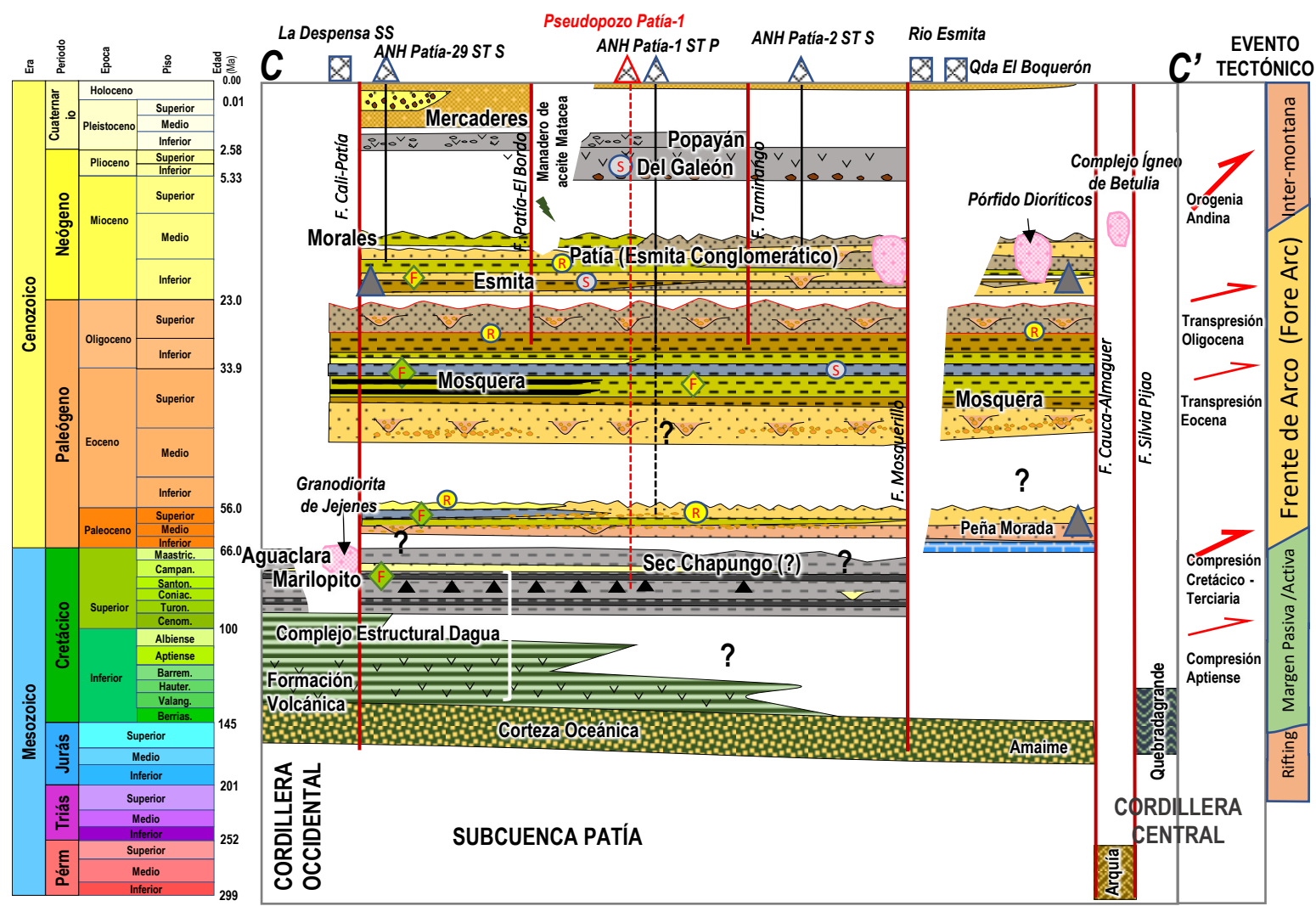
CHRONOSTRATIGRAPHY CAUCA-PATÍA

Cross Section B-B'

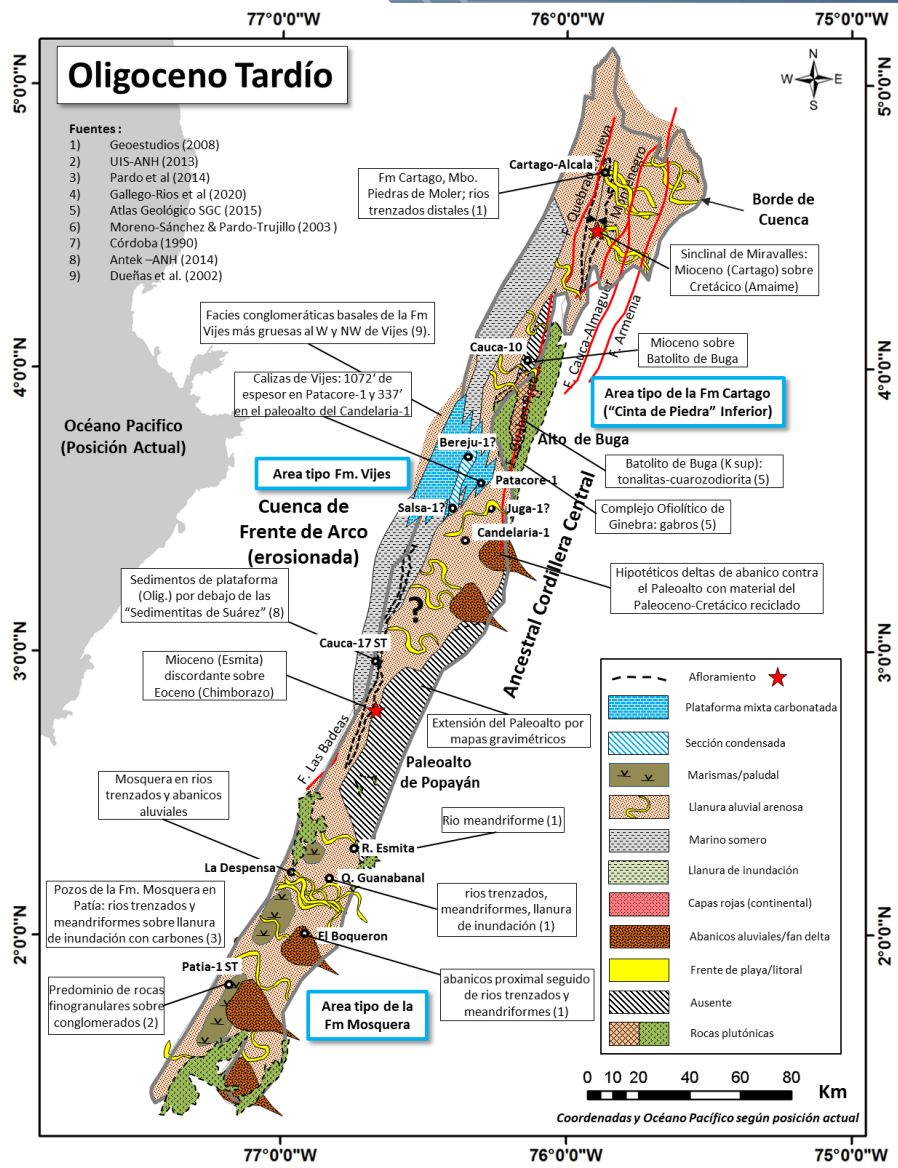
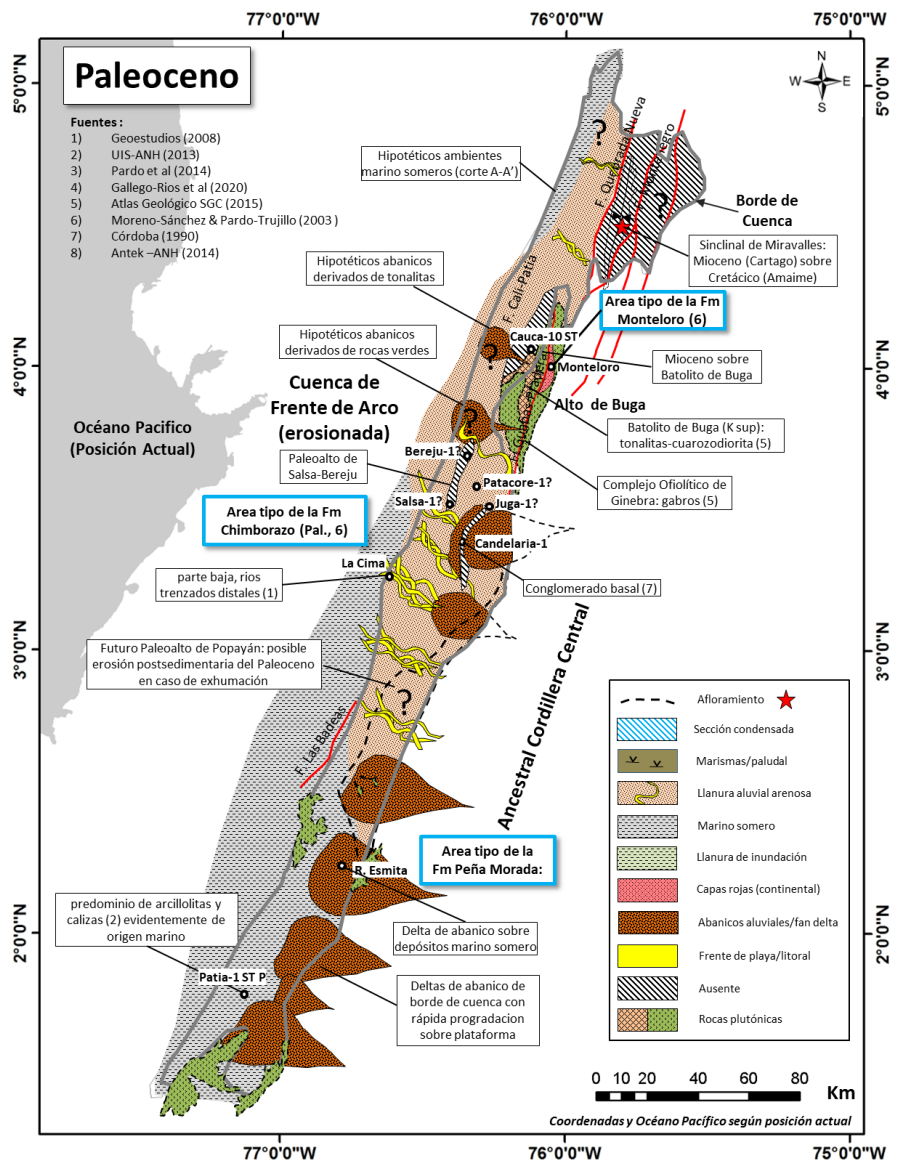


CHRONOSTRATIGRAPHY CAUCA-PATÍA

Cross Section C-C'

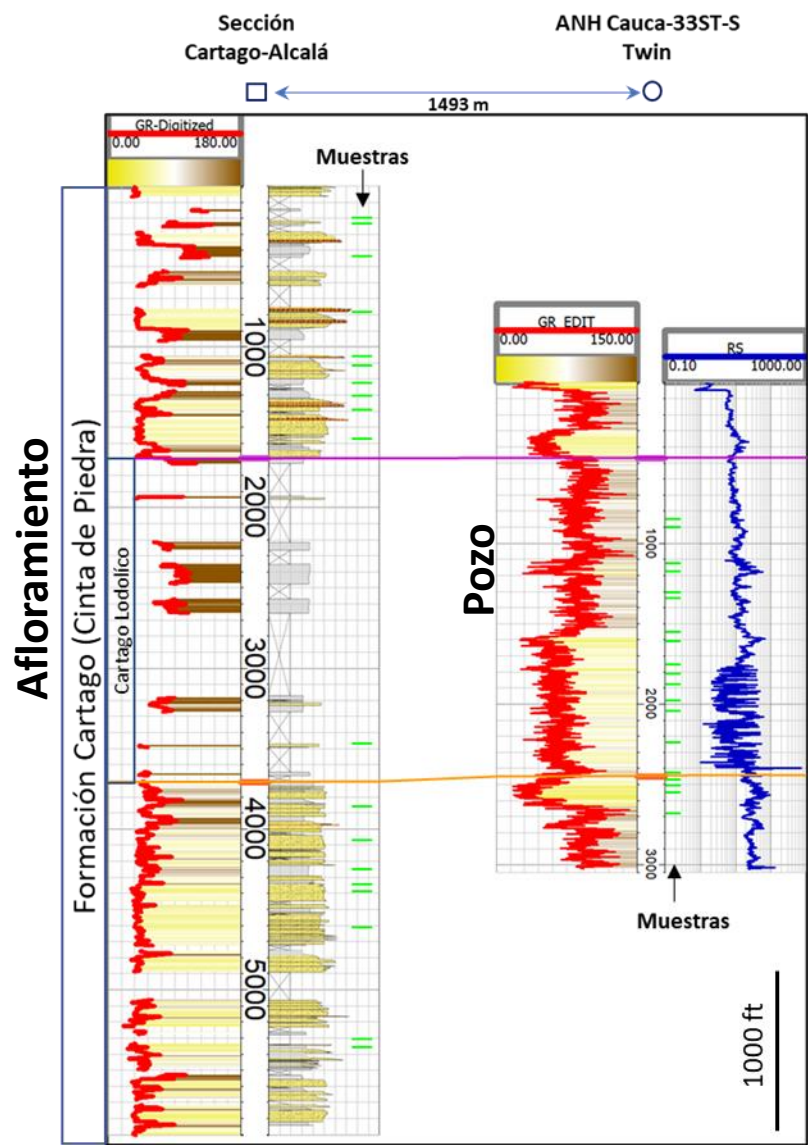


PALEOGEOGRAPHIC MAPS

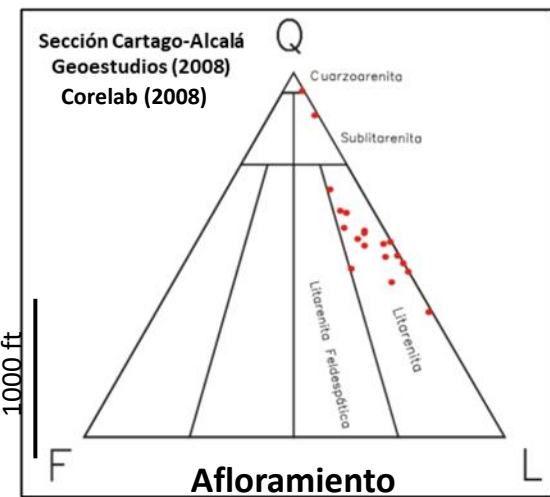
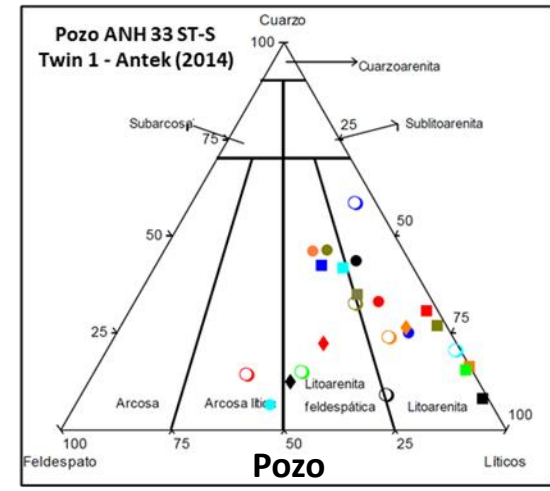


RESERVOIR EVALUATION

Lithological Composition of Surface and Well Samples



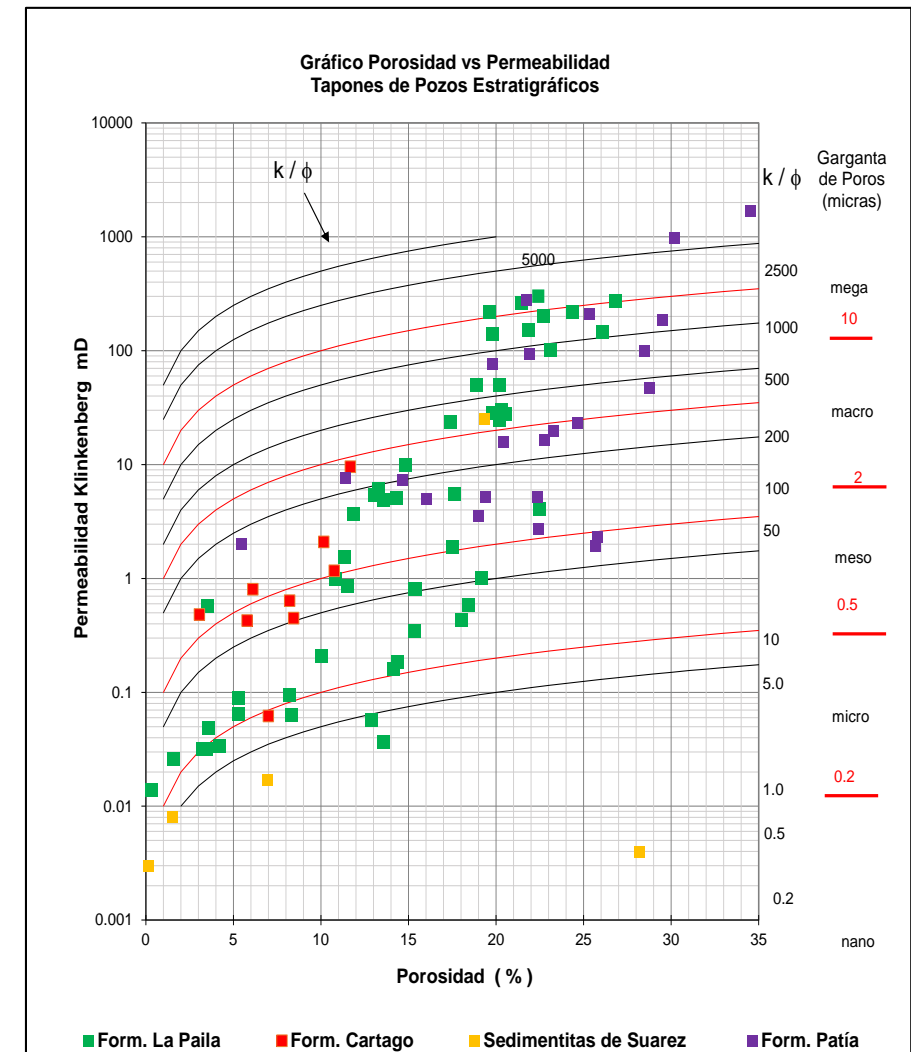
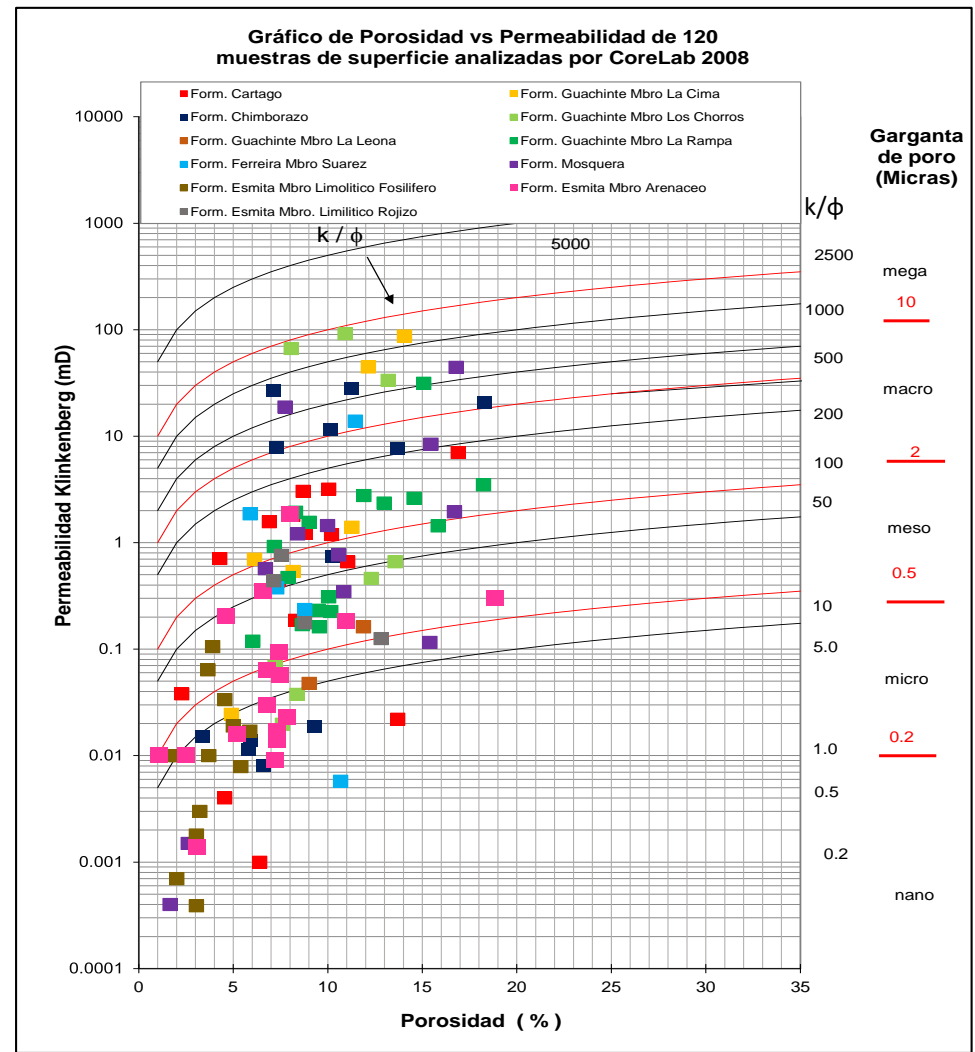
Clasificación Composicional Folk (1974)



- In the samples from the wells dominate the lithoarenites
- In outcrop there is only one sample of quartz-arenite and one sublitho-arenite
- Although the sampling is differential across the section, the overall composition is similar

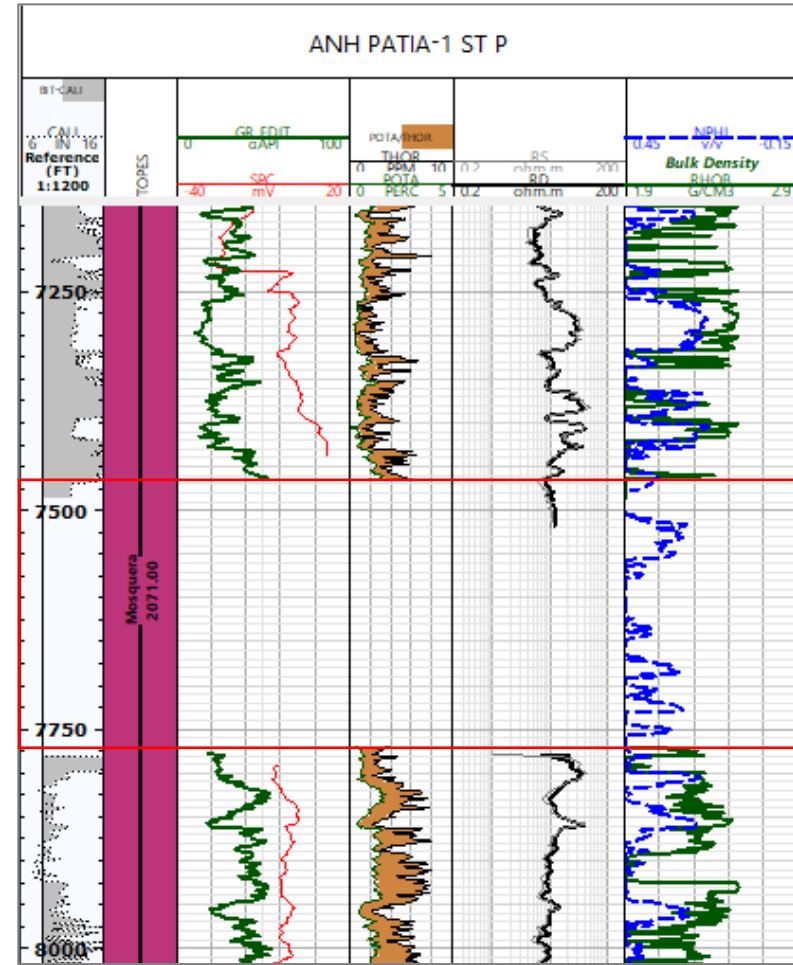
RESERVOIR EVALUATION

Porosity and Permeability Charts for Surface and Wells Samples

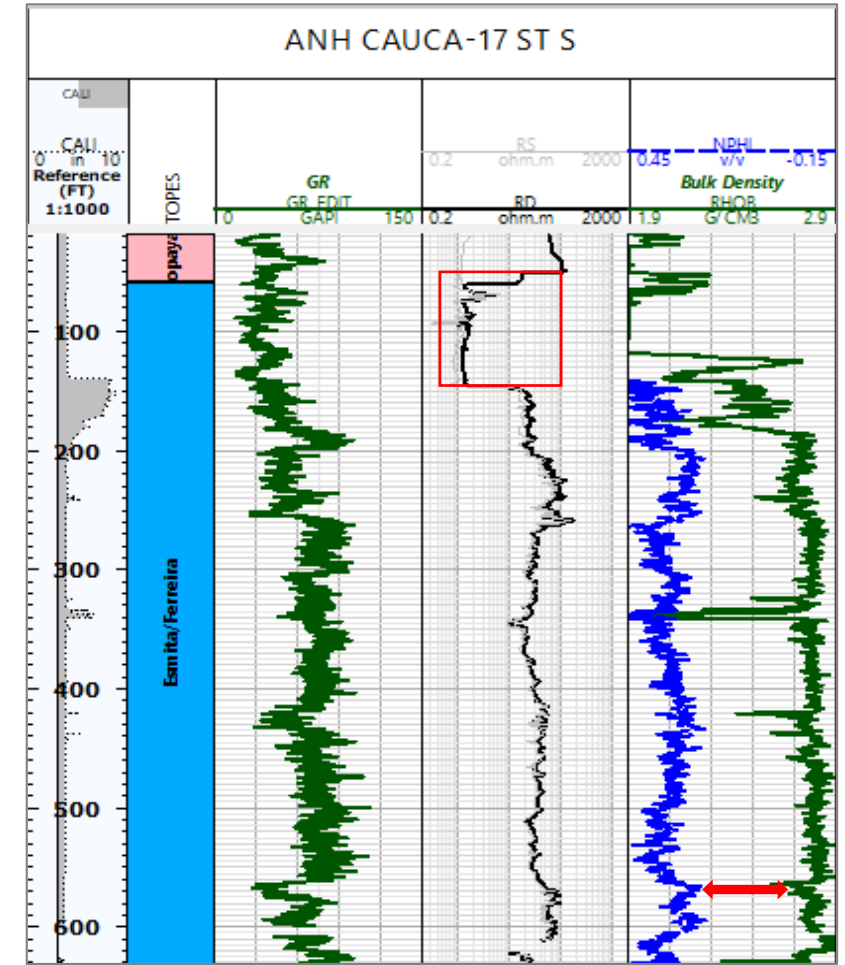


PETROPHYSICAL ANALYSIS OF ELECTRIC LOGS

Quality of Electrical Logs



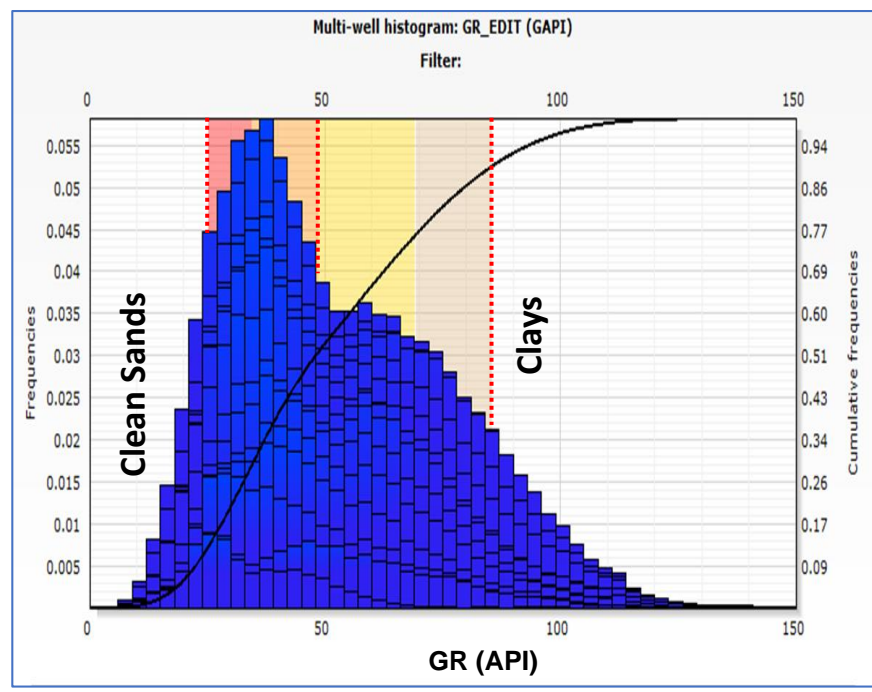
No registration
Caving - Poor hole condition



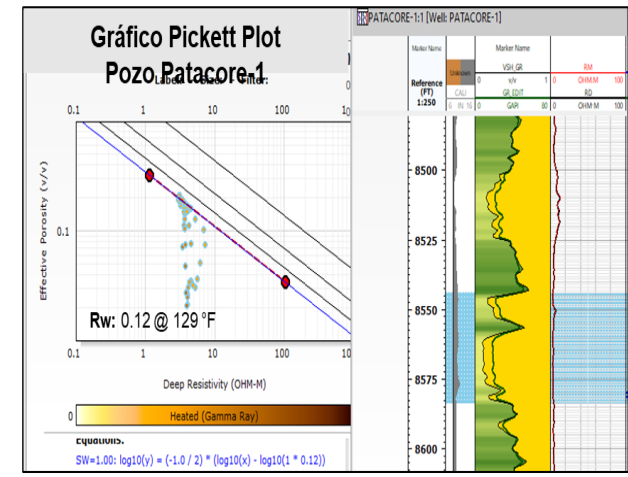
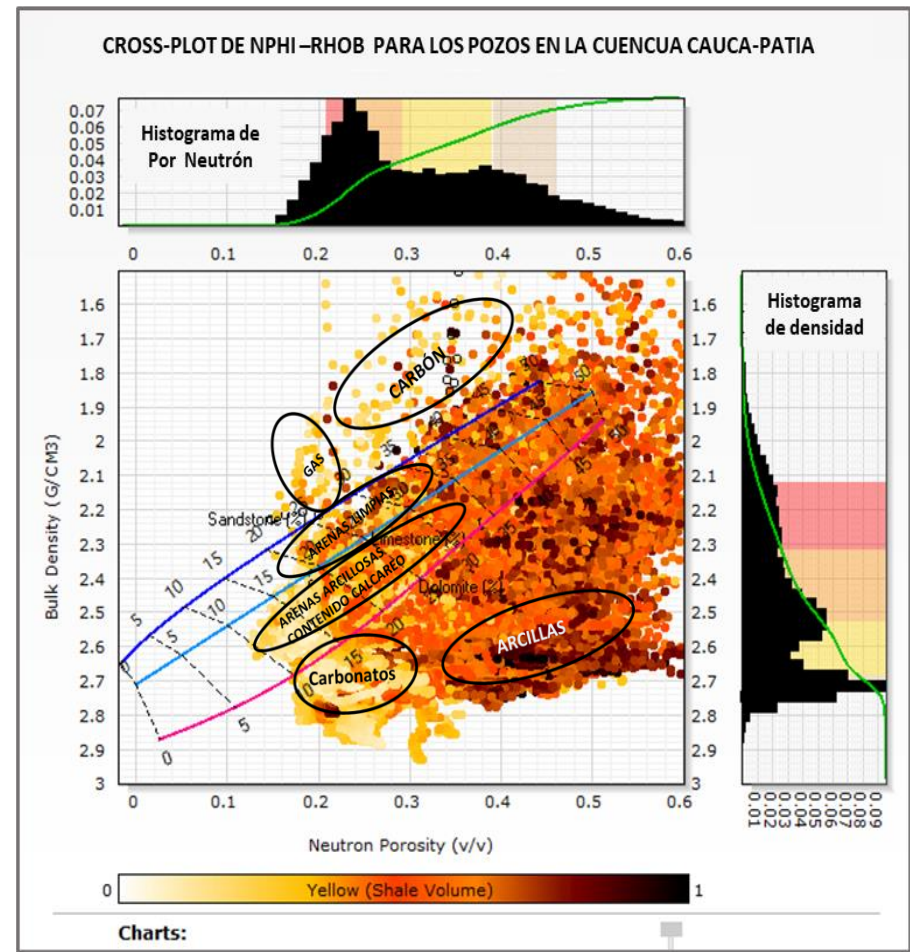
Unreliable Resistivity and Density/Neutron Readings

PETROPHYSICAL ANALYSIS OF ELECTRIC LOGS

Clayey Sands - Abundant high-density minerals - Absence of control of formation fluids



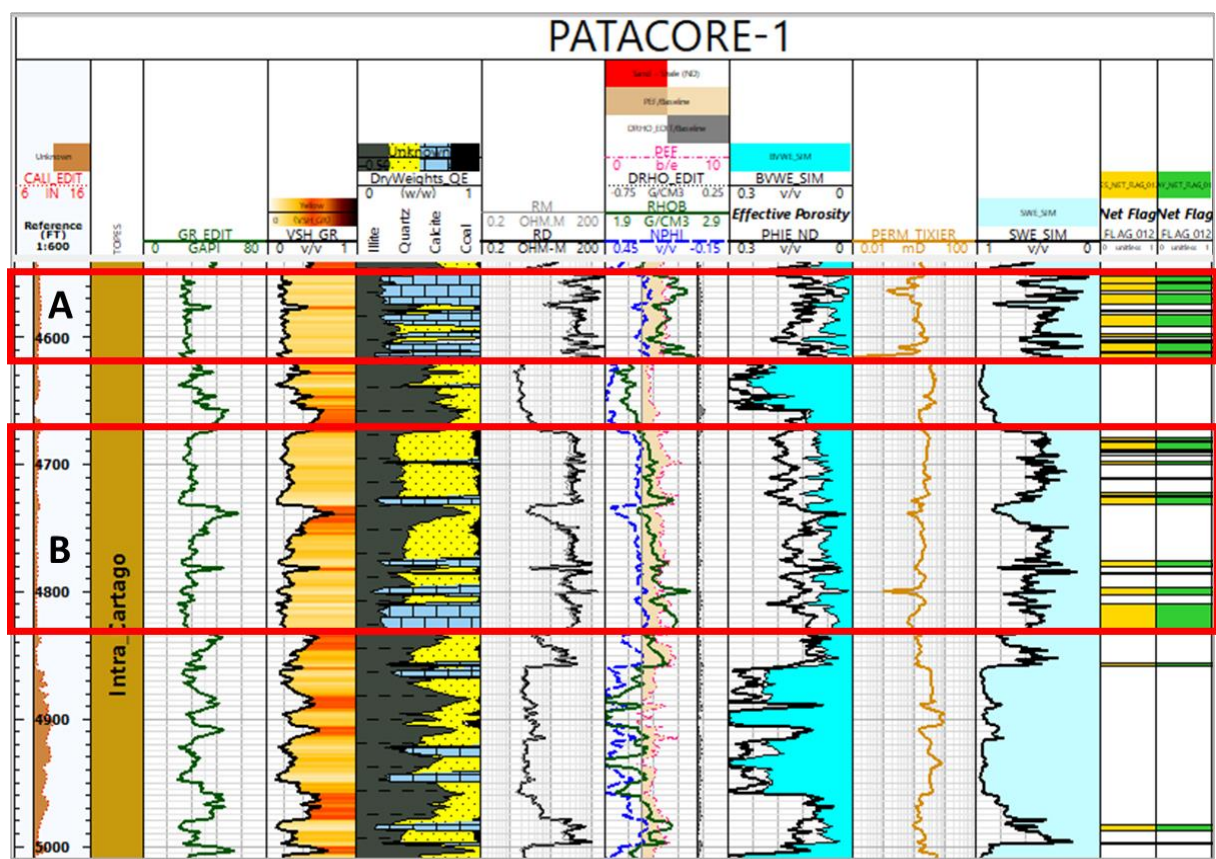
❖ Log-Normal distribution of GR there is no clear separation between clean sands and clays



Formation Water Salinity 24000-30000 ppm NaCl

RESERVOIR EVALUATION

Petrophysical analysis of a section with possible pay - HYDROCARBONS CASE



ZONA	Intervalo (MD)		Espesor Gross (Ft)	Reservorio Net (Ft)	Net Pay (Ft)	VCL (v/v)	PHIE (v/v)	SW (v/v)
	Tope (Ft)	Base (Ft)						
A	4550	4620	70	40	38.5	0.23	0.12	0.37
B	4675	4828	153	55	55	0.23	0.13	0.36

- Possible Pay calculated in the Patacore -1 well
- Other companies in 1997 calculated pay in their petrophysical analyses and recommended testing
 - HBC Registered Engineers
 - Halliburton
 - Diacomp Ltd
- No final geological well reports are found to verify lithology and shows during drilling
- Absence of data on salinity of formation water.

Cutoff 1 from analog basin (Talara Perú)

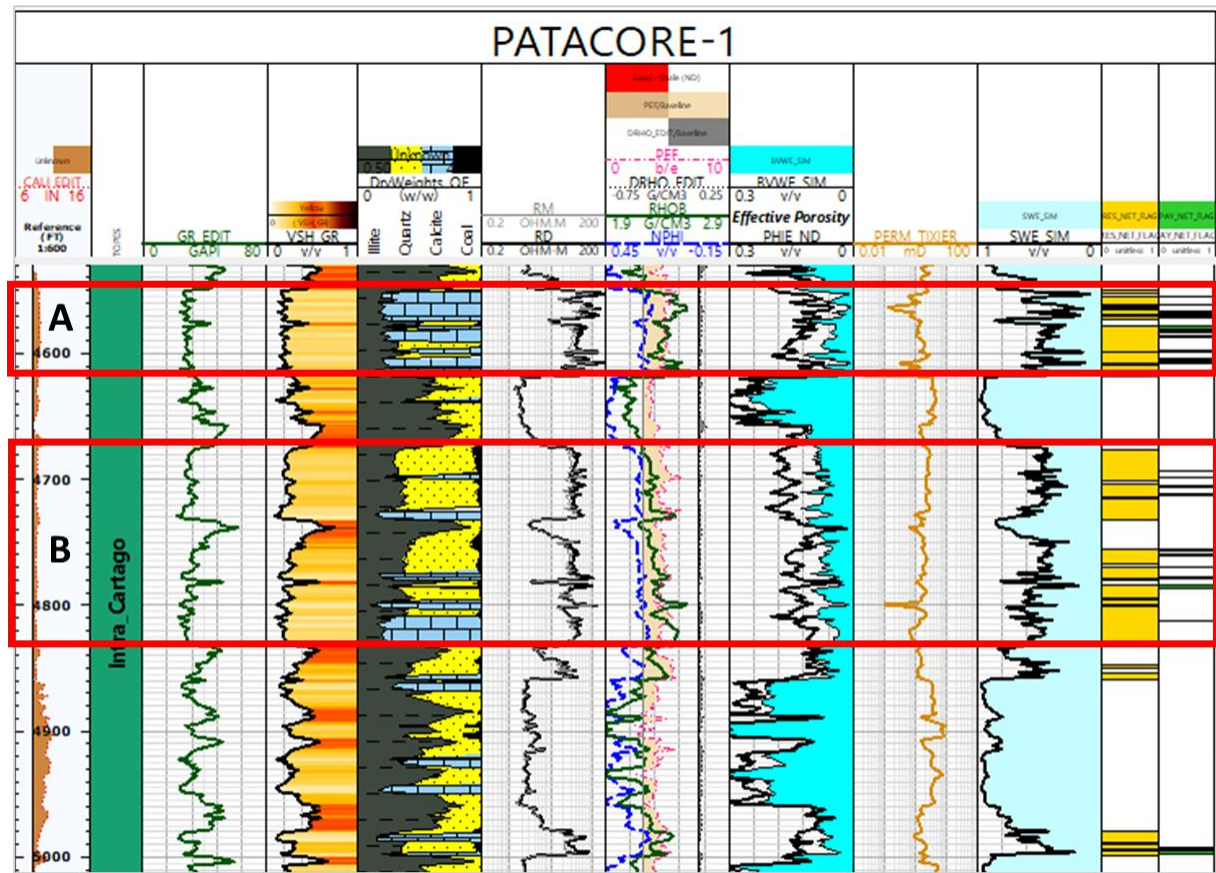
VCL <= 30%

SW <= 65 %

PHIE >= 5%

EVALUACIÓN DE RESERVORIOS

Análisis petrofísico de una sección con posible pay – DRY CASE



- With different cutoff values and using a water salinity of 10000 ppm
- Pay is only calculated at thin intervals less than 2' thick
- Petrophysical calculations indicate that hydrocarbons may exist in this interval; however, the volume is uncertain and can only be verified with additional information from formation fluids
- The petrophysical results presented here are inconclusive

ZONA	Intervalo (MD)		Espesor Gross (Ft)	Reservorio Net (Ft)	Net Pay (Ft)	VCL (v/v)	PHIE (v/v)	SW (v/v)
	Tope (Ft)	Base (Ft)						
A	4550	4620	70	40	8.5	0.19	0.12	0.35
B	4675	4828	153	55	10.5	0.23	0.14	0.33

Cutoff 2

VCL <= 30%

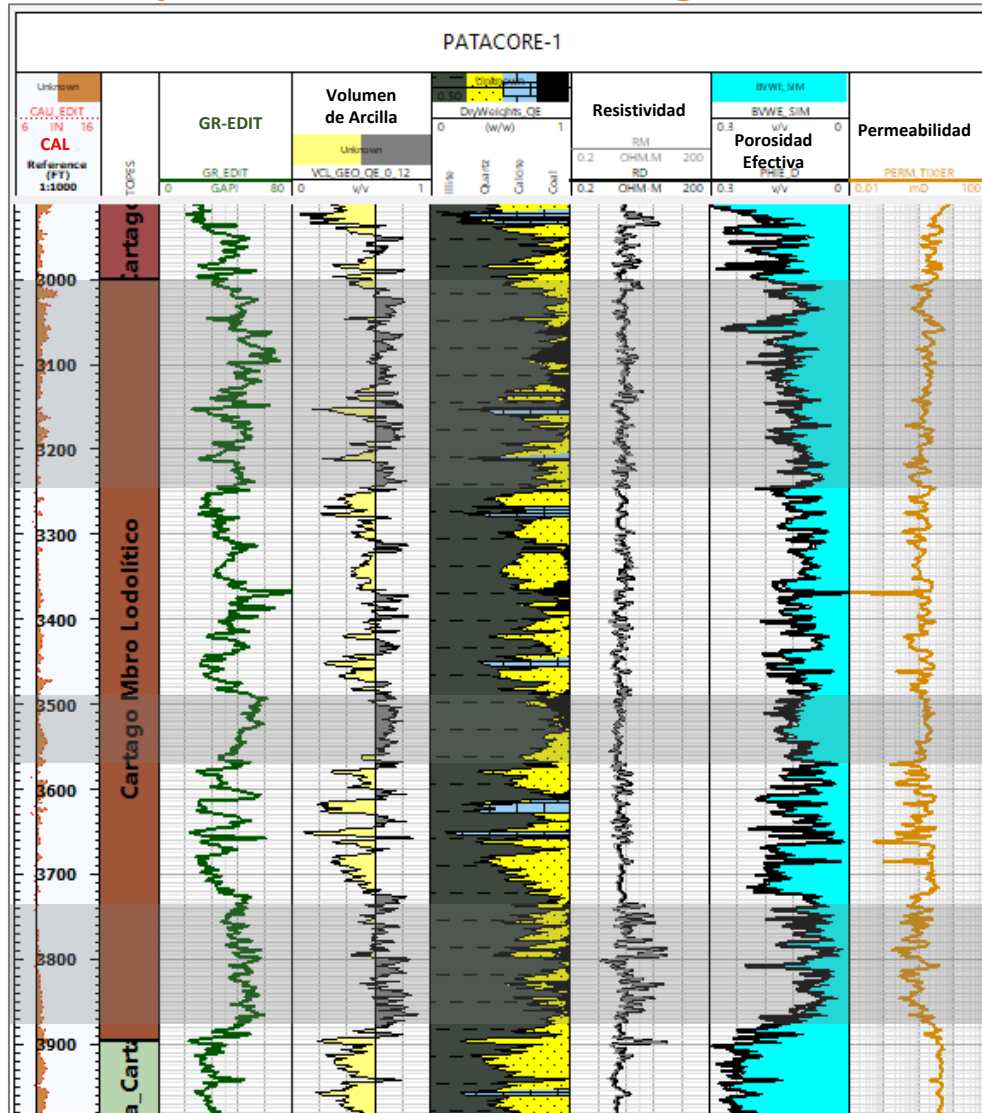
PHIE >= 8%

SW <= 50 %

RD >= 10 Ohm.m

SEALING ROCK EVALUATION

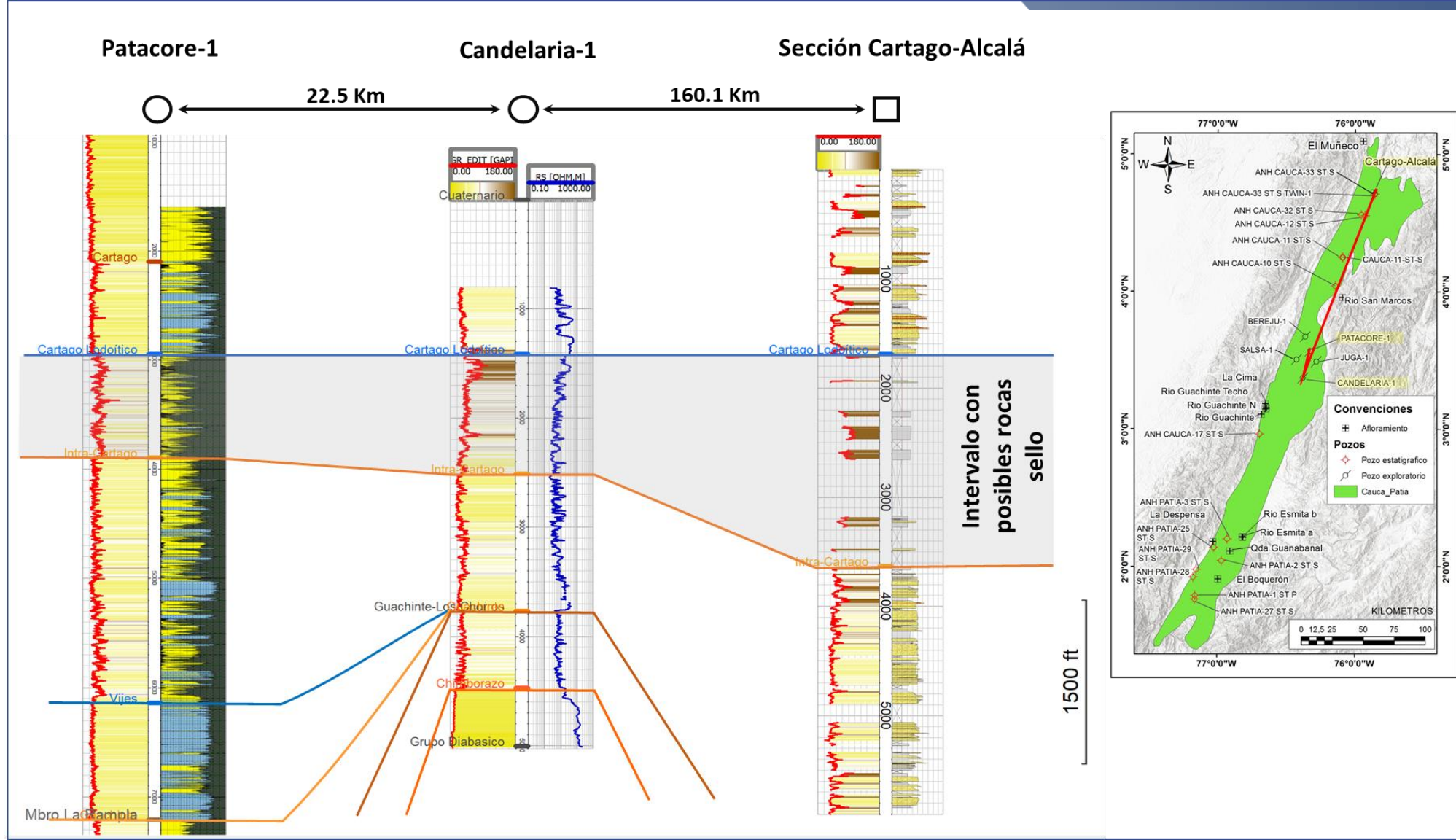
Example of seals in the Cartago Formation



- The Cartago Lodolítico unit is 900' thick in Patacore-1
- Three mudstone intervals are present with
 - Average permeability ≤ 2 mD
 - Clay volume $\geq 60\%$
- This interval is present regionally along the Cauca sub-basin and could be a regional seal

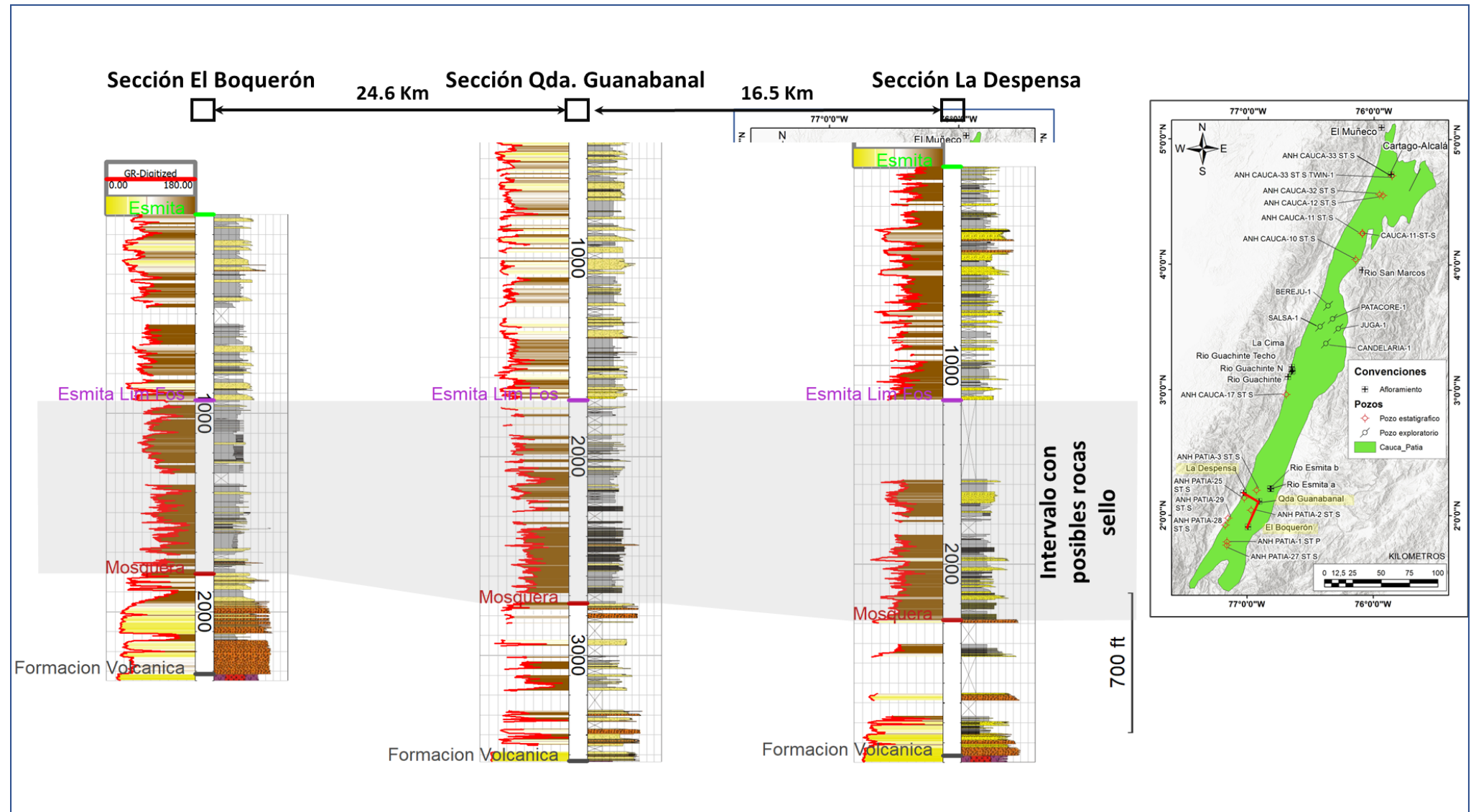
SEALING ROCK EVALUATION

Example of sealing rocks in the Cartago Formation



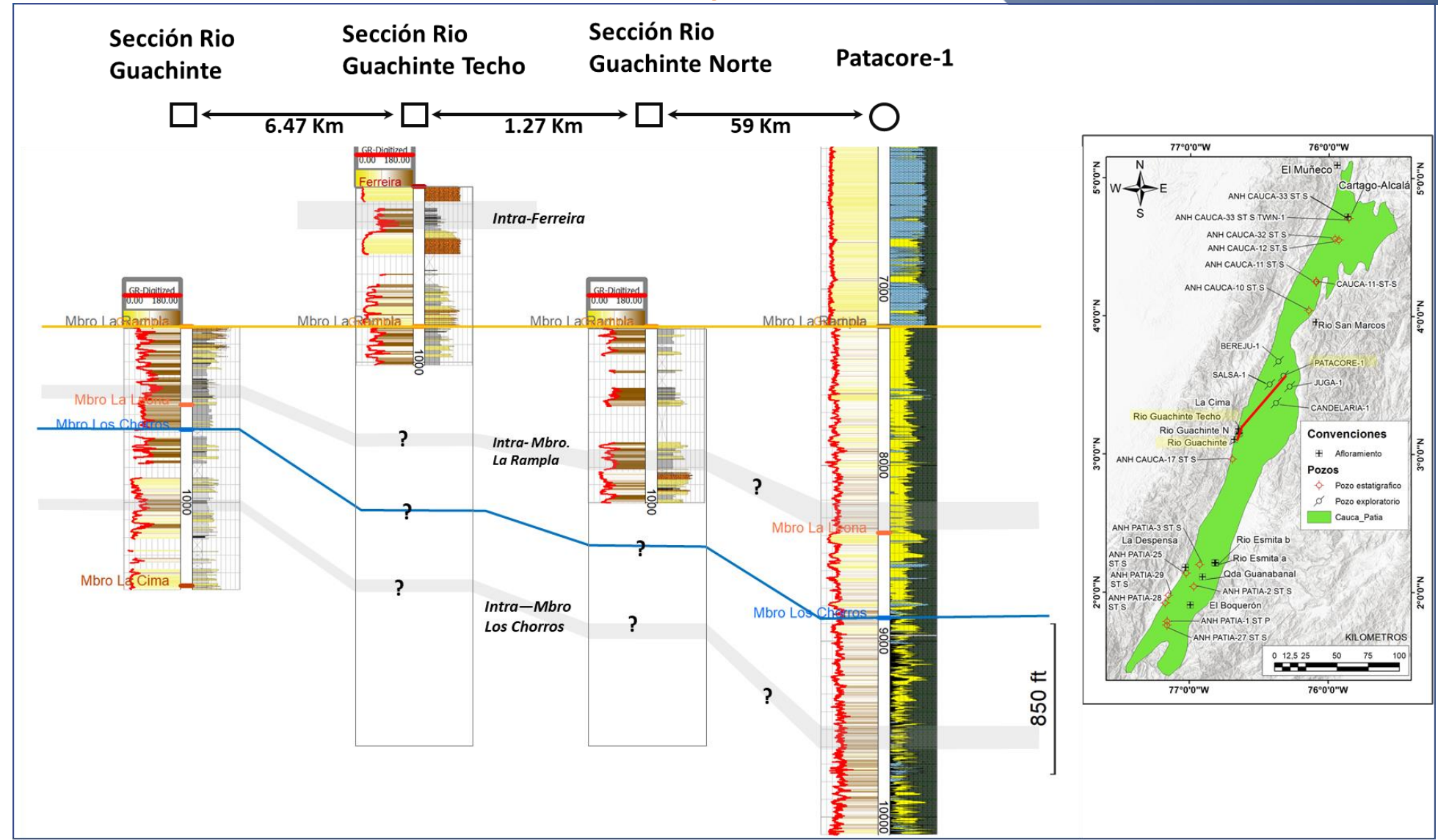
SEALING ROCK EVALUATION

Example of sealing rocks in the Esmita Formation



SEALING ROCK EVALUATION

Intraformational Seals Fm Guachinte, Mbrs La Rampla and Chorros



SUMMARY OF RESERVOIRS

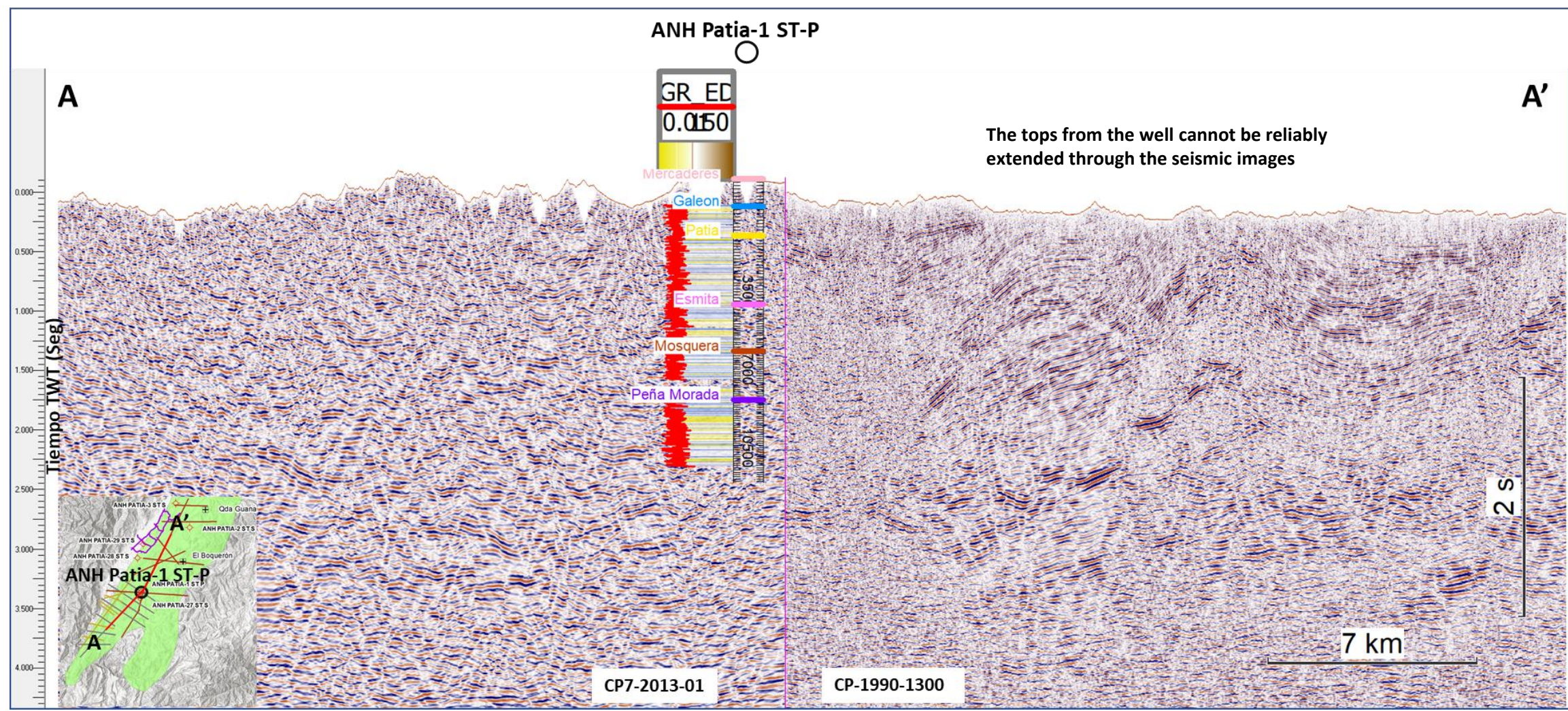
Outcrop and well samples

DATA	FORMATION	Member	Lithology	Porosity (%)		Permeability (mD)		Depos. Envir	Reservoir Potential	
				Max	Average	Max	Average			
Core Plug Samples (Antek 2014)	La Paila		Sandstone	26.8	13.8	302.29	50.11	Braided and Meandering Rivers**	Good	
			Conglomerate	19.8	17.5	141.2	49.0			
			Calcarenites	22.5	17.4	50.6	14.5			
	Patia*		Sandstone	30.2	21.8	971.0	107.4		Good	
			Conglomerate	40.3	25.1	6627.0	1669.7			
		Sedimentitas de Suarez (Equiv. a Esmita)		Sandstone	28.2	4.5	25.4		2.8	Playa
Cartago (Cinta de Piedra)			Sandstone	11.7	6.6	9.6	1.4	Braided and Meandering Rivers**	Poor	
			Calcarenites	7.0	3.9	0.1	0.0		No	
Outcrop Samples (Geoestudios 2008)	Esmita	Arenáceo	Sandstone	18.8	7	1.9	0.2		Very Poor	
		Limolítico Fosilífero	Sandstone	5.9	3.4	0.1	0.0		No	
		Limolítico Rojizo	Sandstone	12.8	9.1	0.8	0.4		No	
	Ferreira	Suárez	Sandstone	11.5	8.8	13.9	3.3		Poor	
	Mosquera		Sandstone	16.8	9.8	44.4	7.1		Moderate	
	Cartago (Cinta de Piedra)			Sandstone	16.9	8.5	7		1.5	Poor
	Guachinte	La Rampla	Sandstone	18.2	10.9	31.5	3.1		Moderate	
		La Leona	Sandstone	11.9	10.4	0.2	0.1		No	
		Los Chorros	Sandstone	13.6	10.1	91.9	24.2	Good		
		La Cima	Sandstone	14.1	9.4	87.2	22.4	Good		
Chimborazo	Loma Larga	Sandstone	18.3	10.1	27.9	11.0	Moderate			
Peña Morada (Only 2 Samples)			Sandstone	0	0			Indetermined		
*	Does not include data from the ANH-Patia 2 ST-S and ANH-Patia 25ST-S wells since the permeability values were zero									
**	The thickness of the sandstone and conglomerate units range from 1m to stacked packages of 80m									

Seismic Interpretation Structural models of the basin

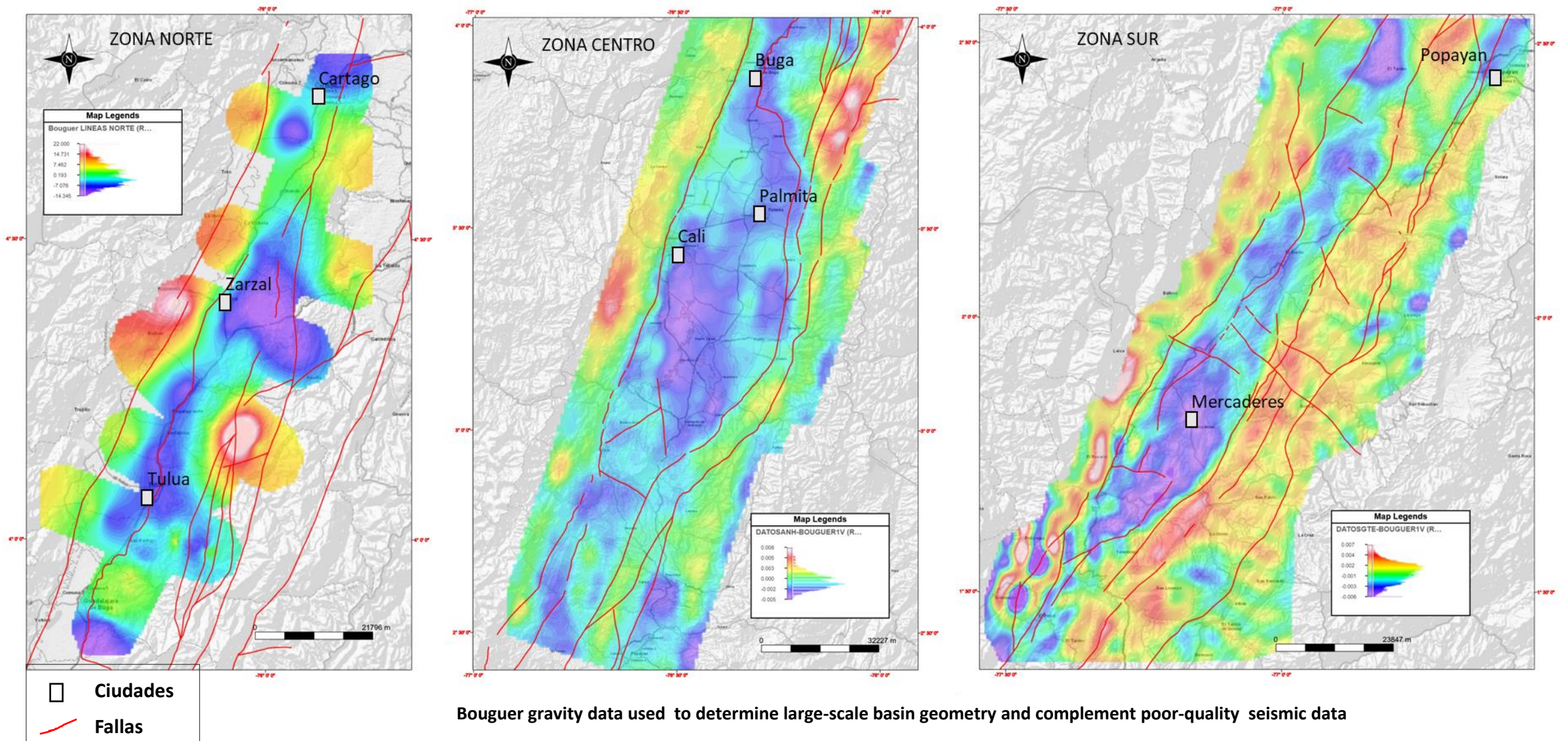
SEISMIC INTERPRETATION

Seismic Quality Contrast



BOUGUER GRAVITY DATA

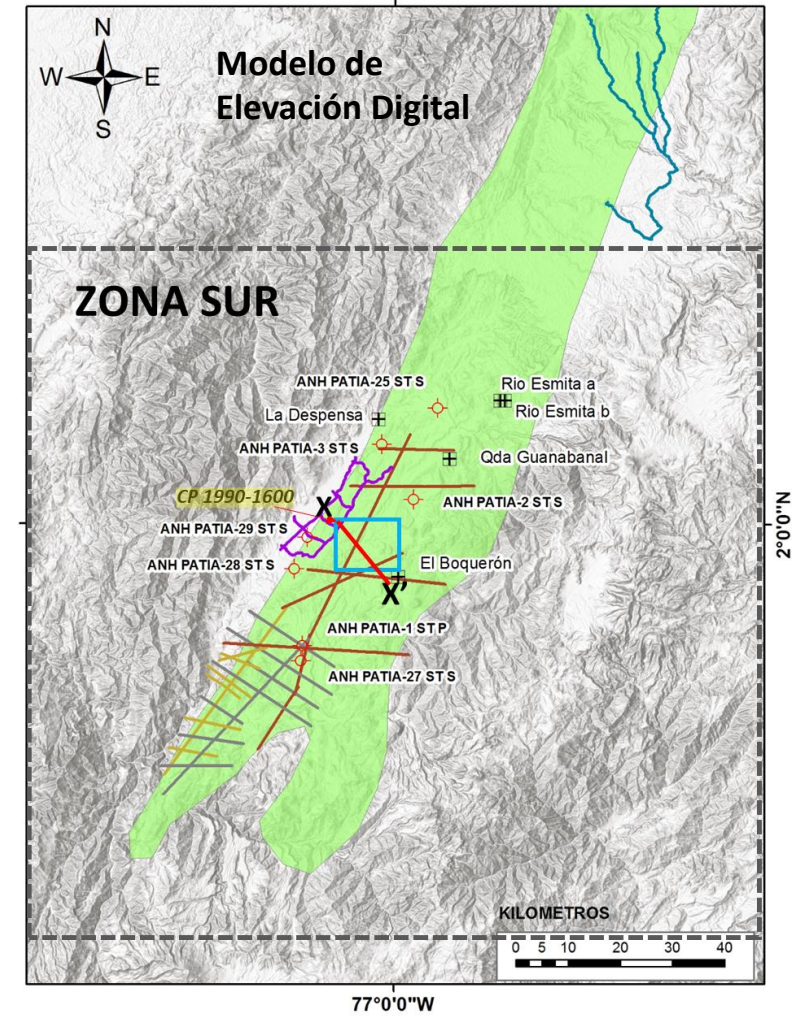
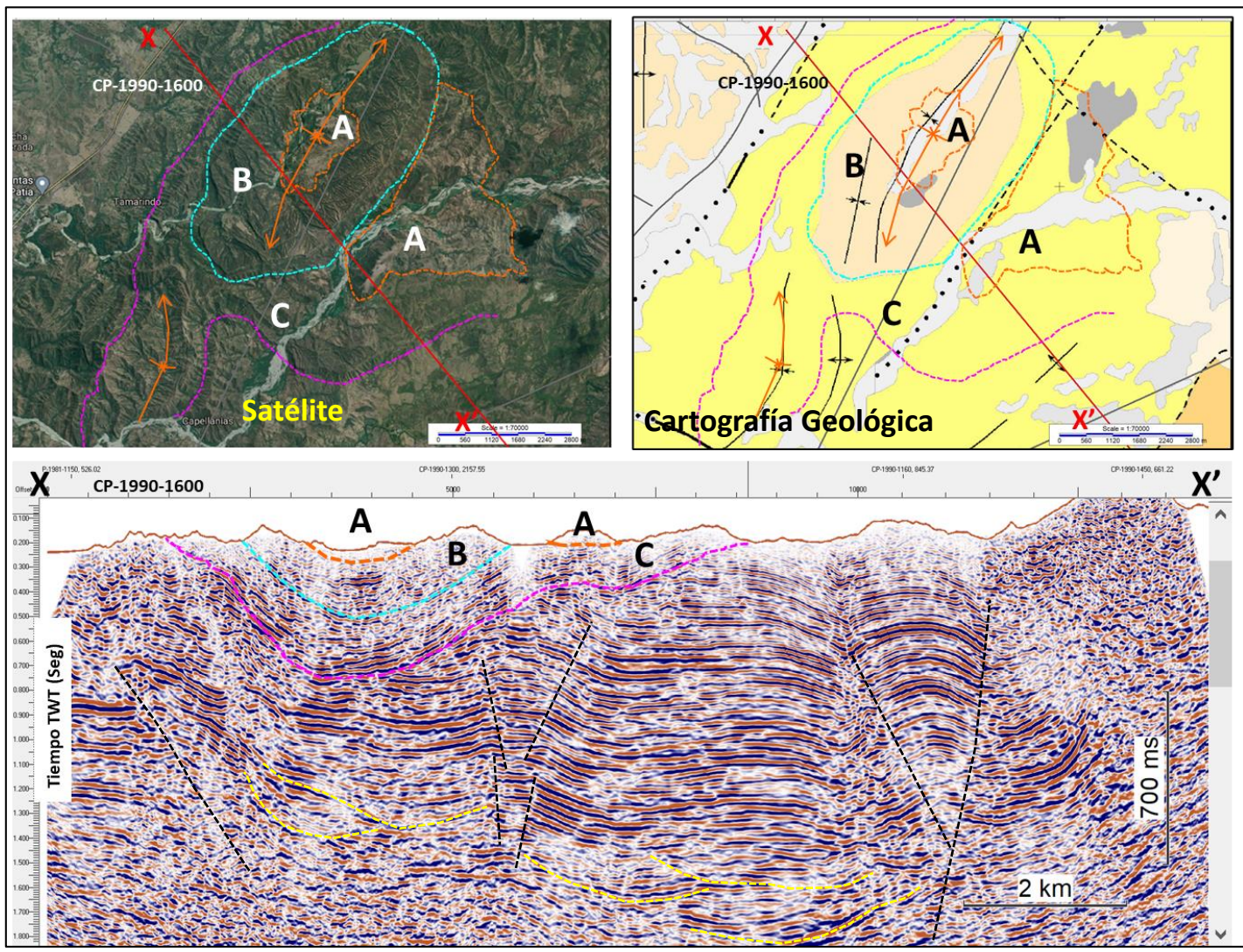
Depocenters in the North, Central and South zones



Bouguer gravity data used to determine large-scale basin geometry and complement poor-quality seismic data

SEISMIC INTERPRETATION

Use of surface information to support the seismic interpretation

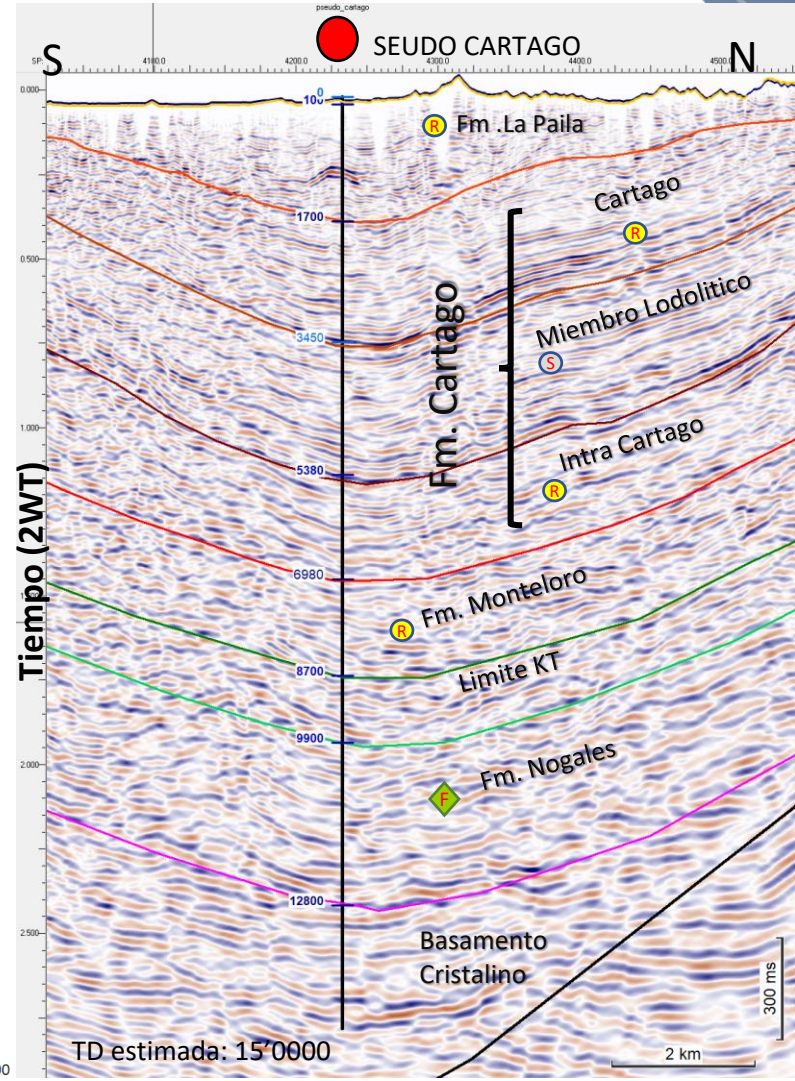
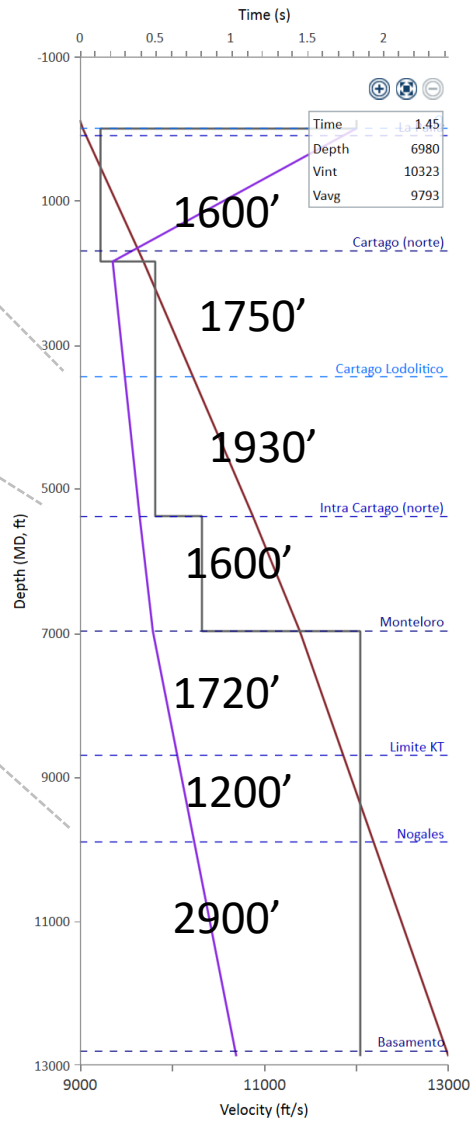
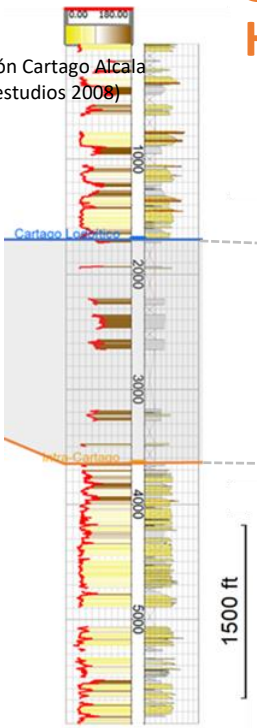


Satellite imagery and surface geology to complement seismic interpretation

SEISMIC INTERPRETATION

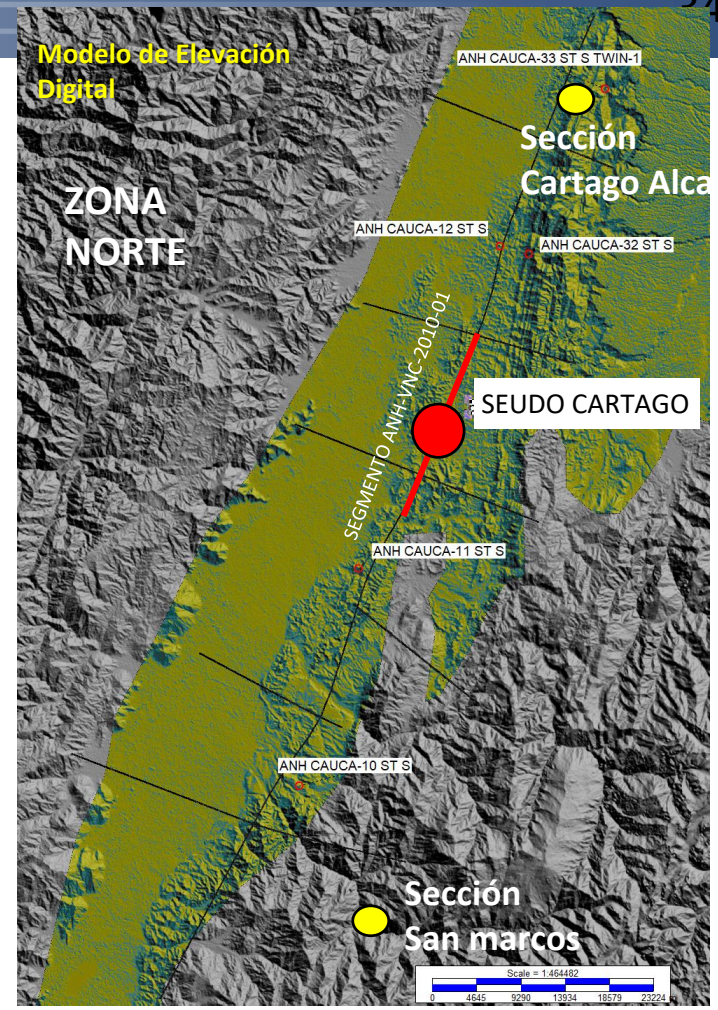
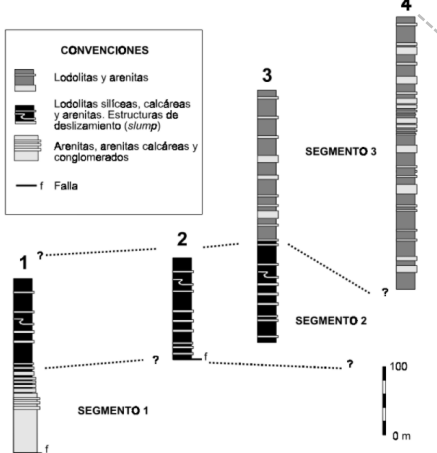
Hypothetical distribution of seismic markers - North Zone

Sección Cartago Alcalá (Geostudios 2008)



Secciones Rio San marcos- Monteloro (Pardo 2002)

- CONVENCIONES**
- Lodolitas y arenitas
 - Lodolitas silíceas, calcáreas y arenitas. Estructuras de deslizamiento (slump)
 - Arenitas, arenitas calcáreas y conglomerados
 - Falla

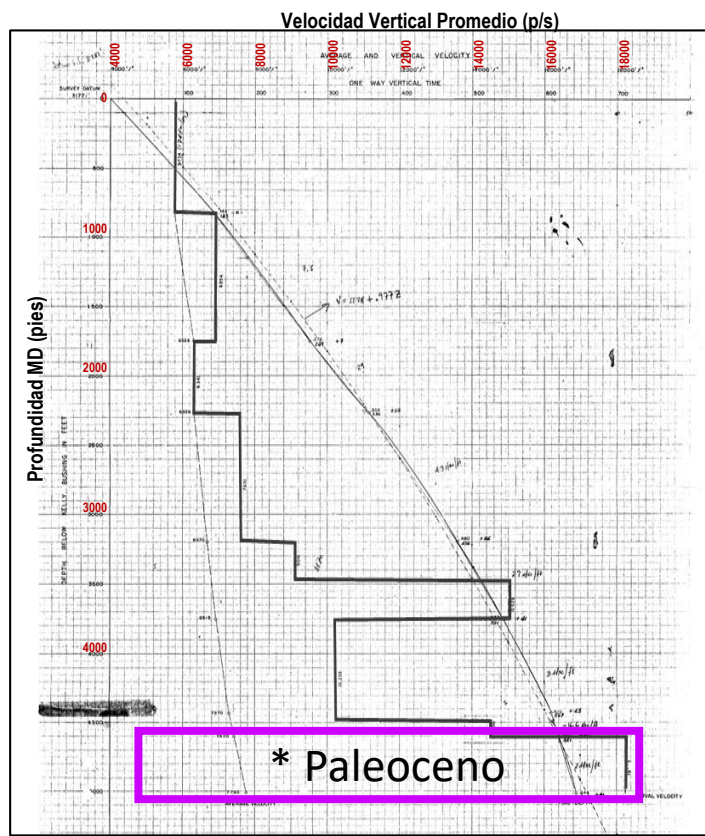


- Sello
- Reservorio
- Roca fuente

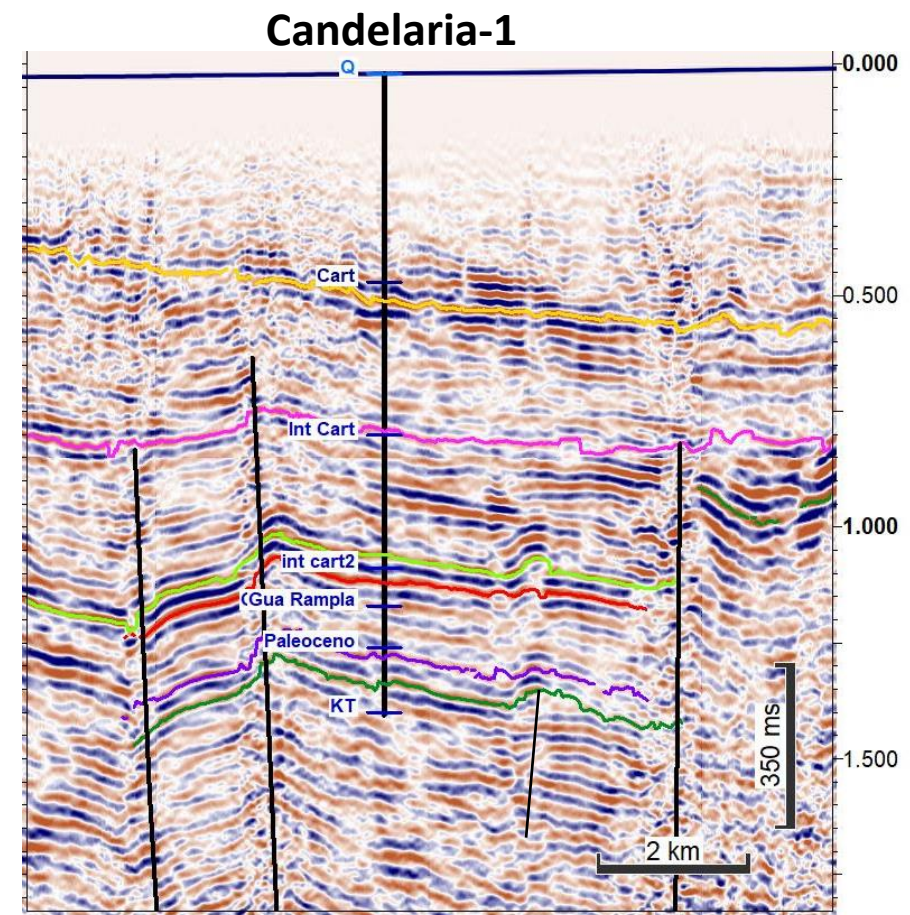
Segmento línea ANH VNC -2010-10

SEISMIC INTERPRETATION

Well to seismic tie – Central Zone

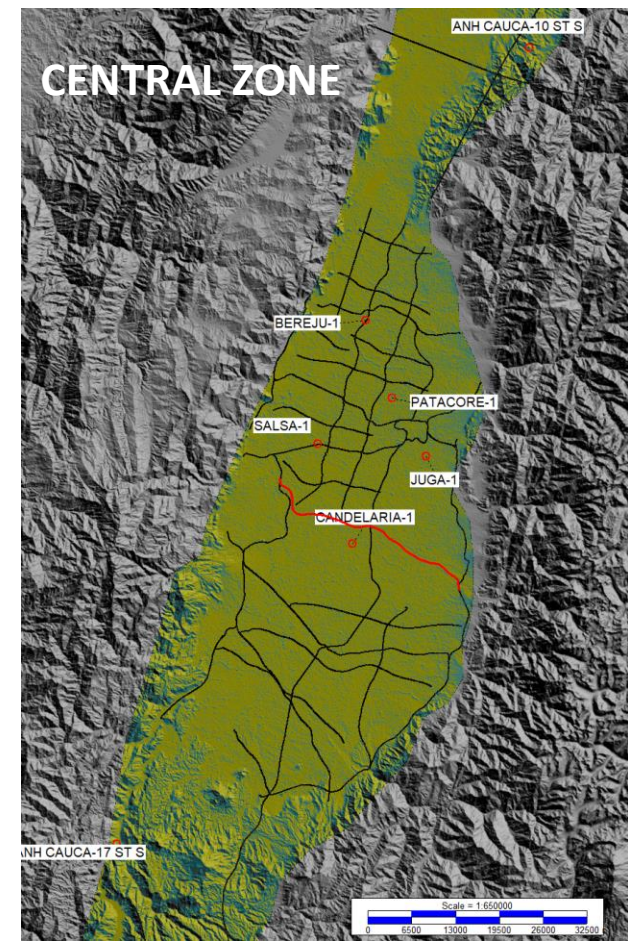
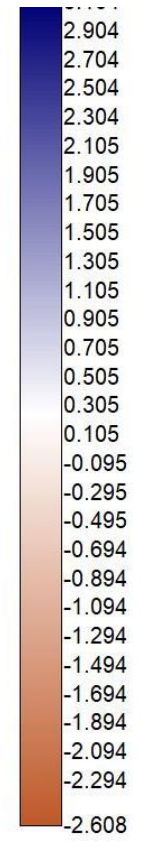


Velocity data
Candelaria-1 TD:5028'
International Petroleum, 1965



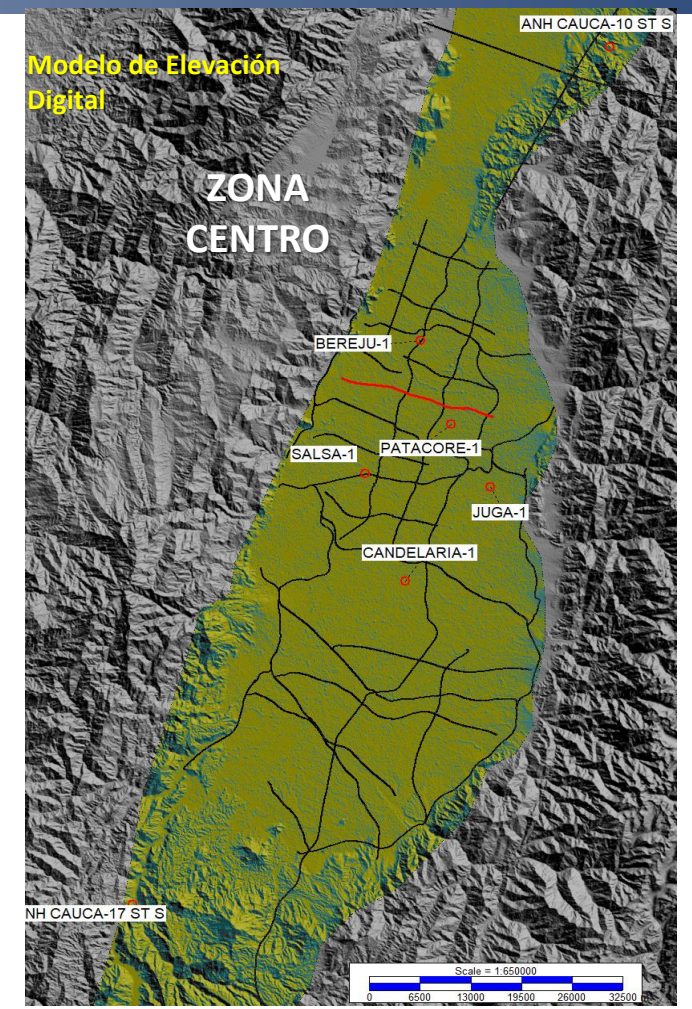
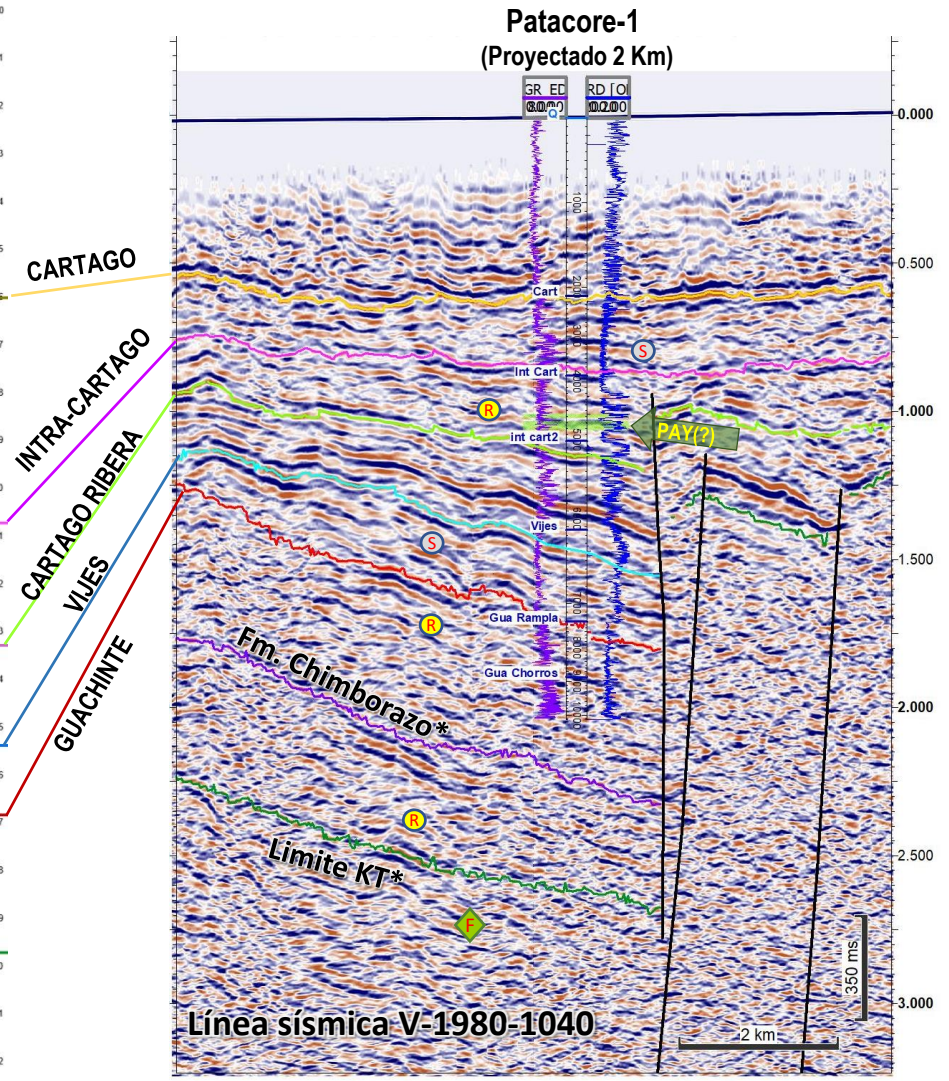
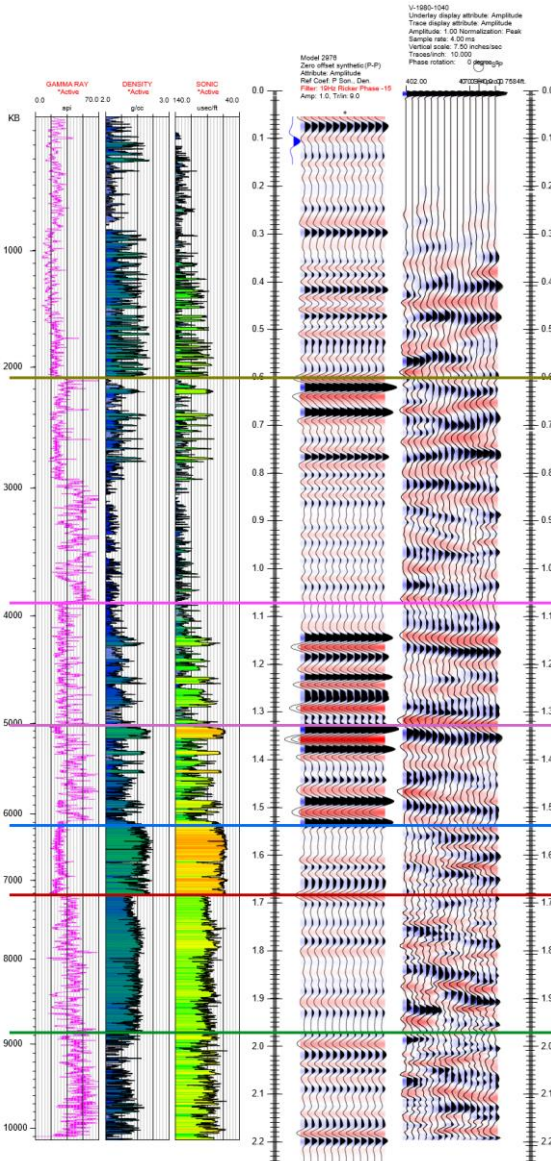
Línea sísmica VC-1979-06

*Top after Córdoba, et al. 1998



SEISMIC INTERPRETATION

Well to seismic tie – Central Zone



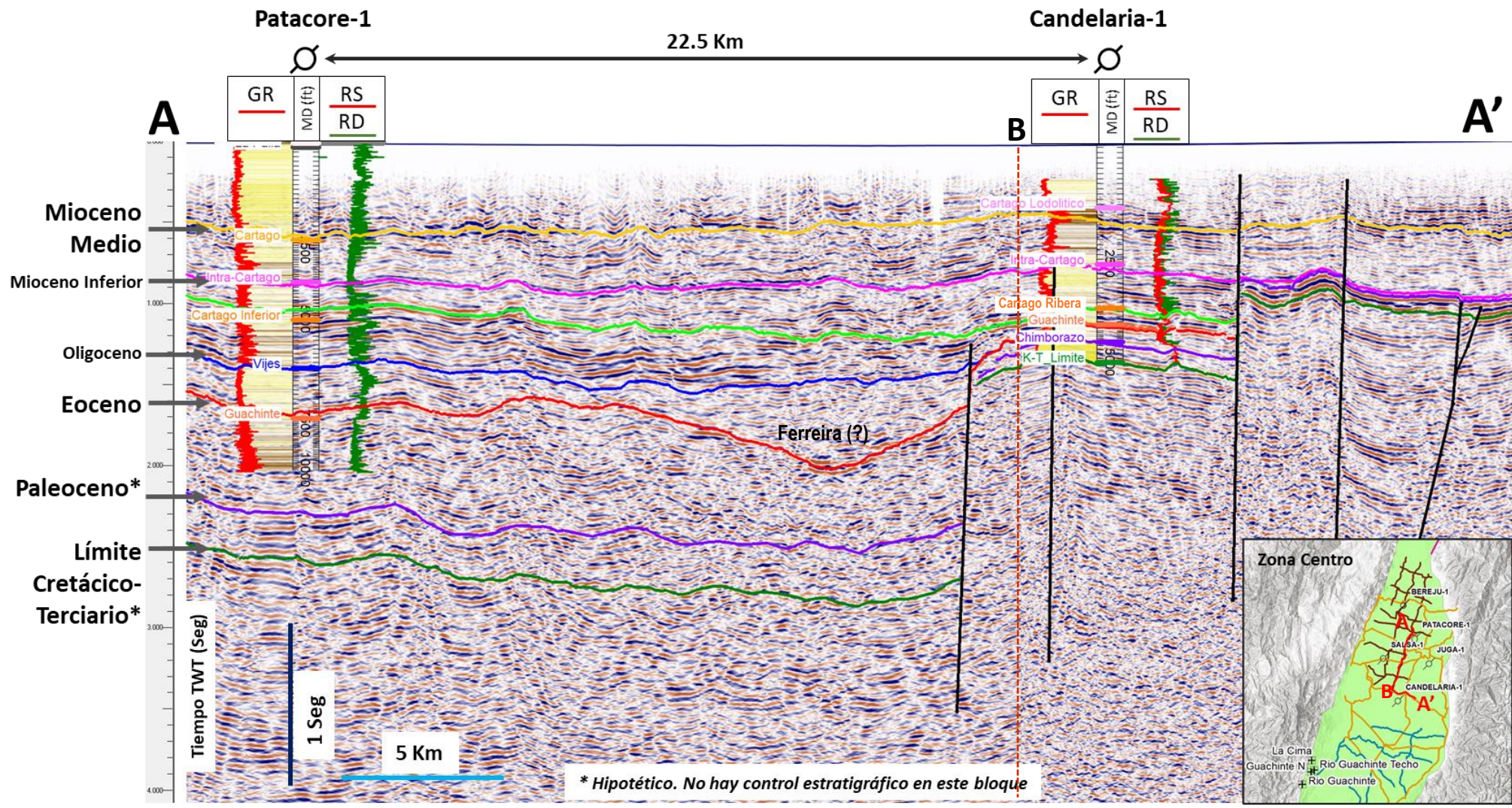
Sismograma Sintético
Pozo Patacore-1 TD: 10142'

* Hipotético

- S Sello
- R Reservorio
- F Roca fuente

SEISMIC INTERPRETATION

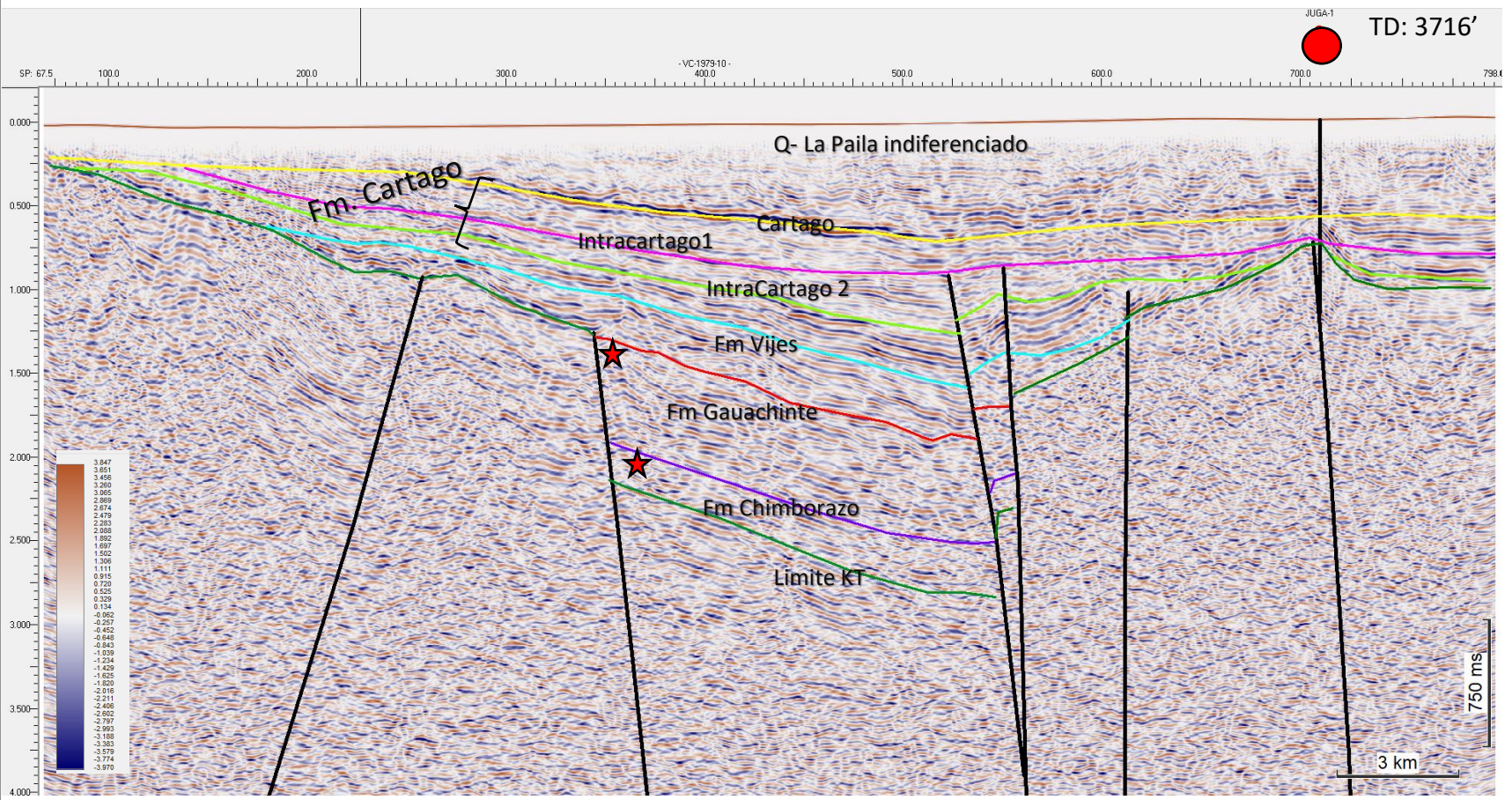
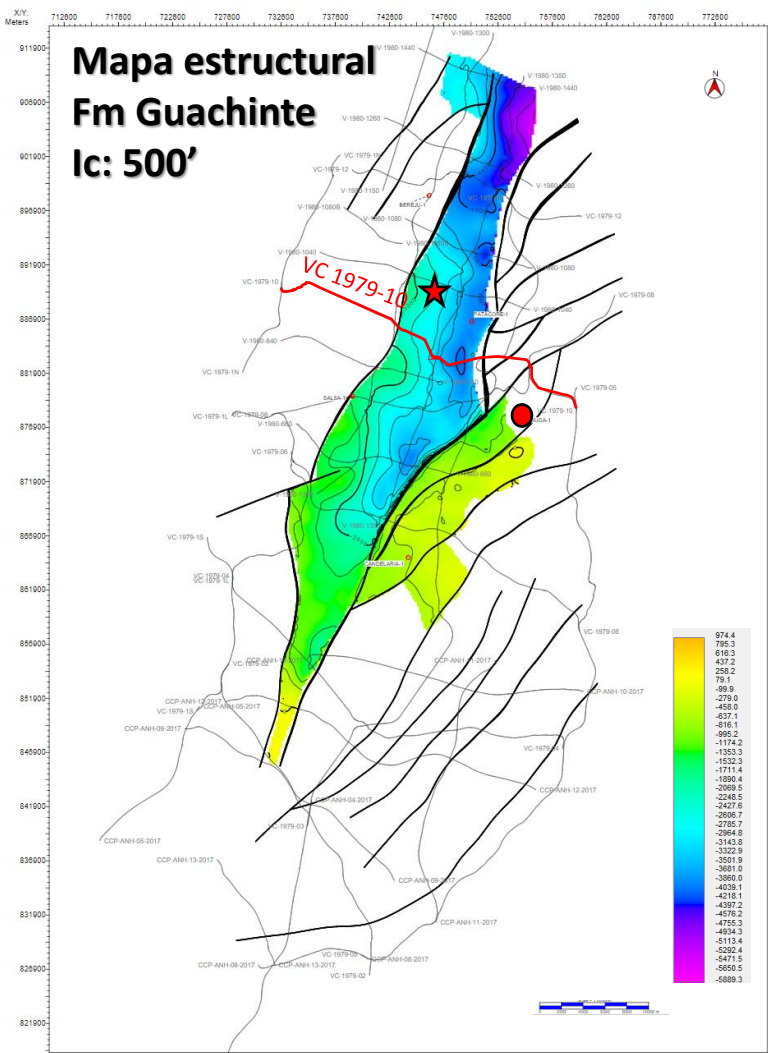
Interpreted Seismic Markers - Center Zone



SEISMIC INTERPRETATION

Interpreted Seismic Markers - Center Zone

LEADS INDETFICADOS

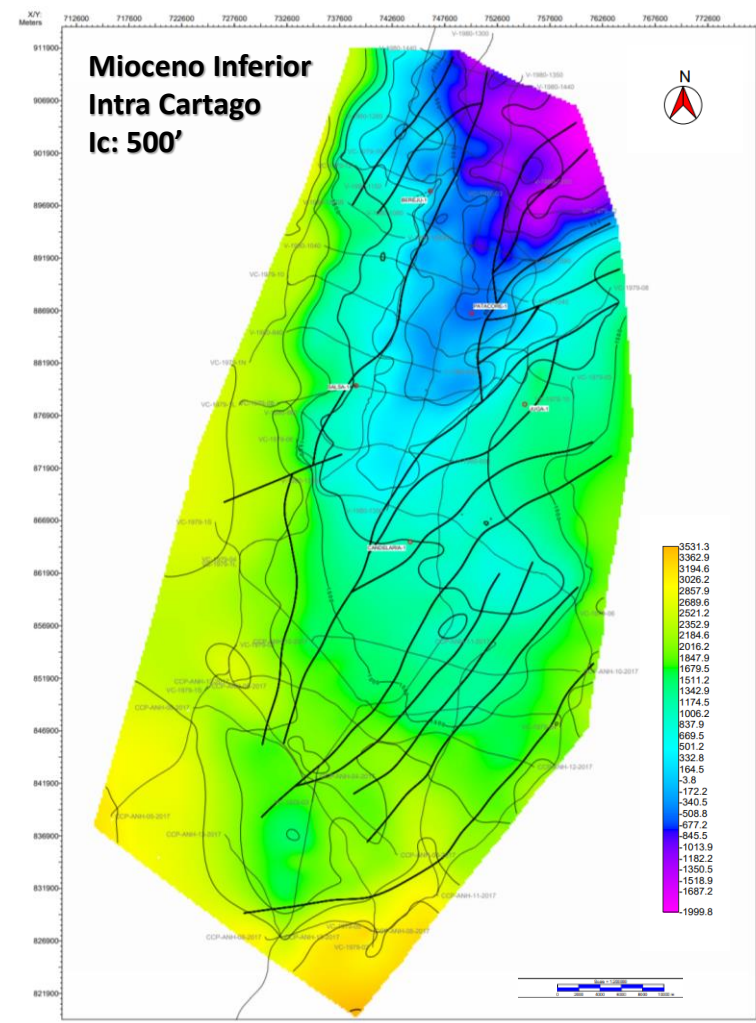
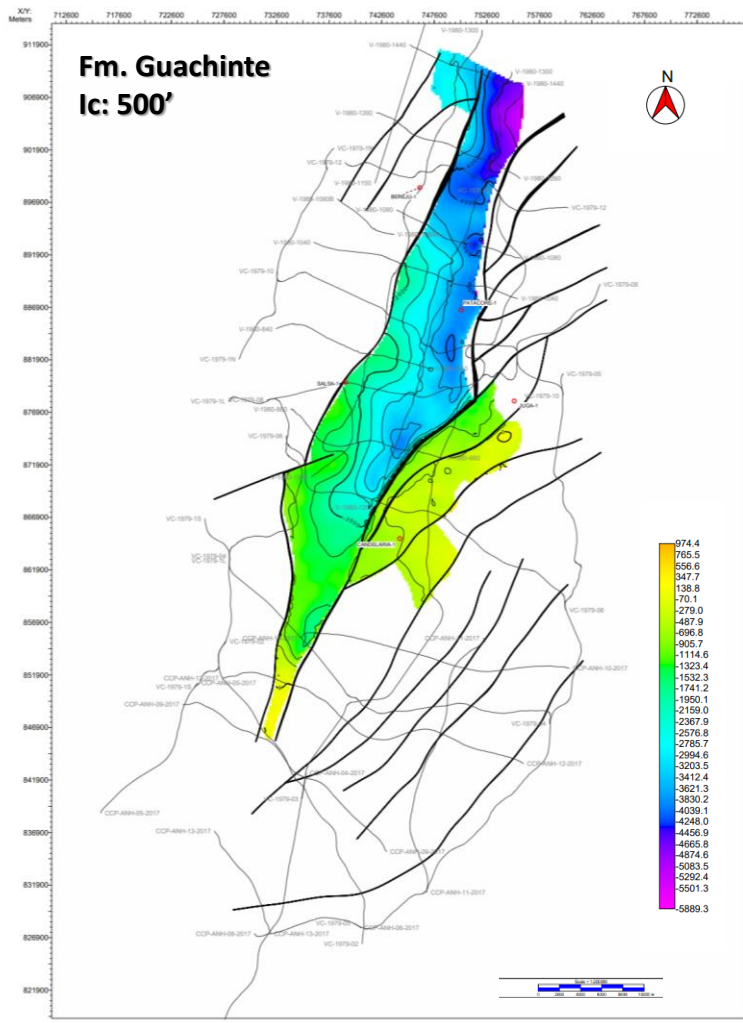
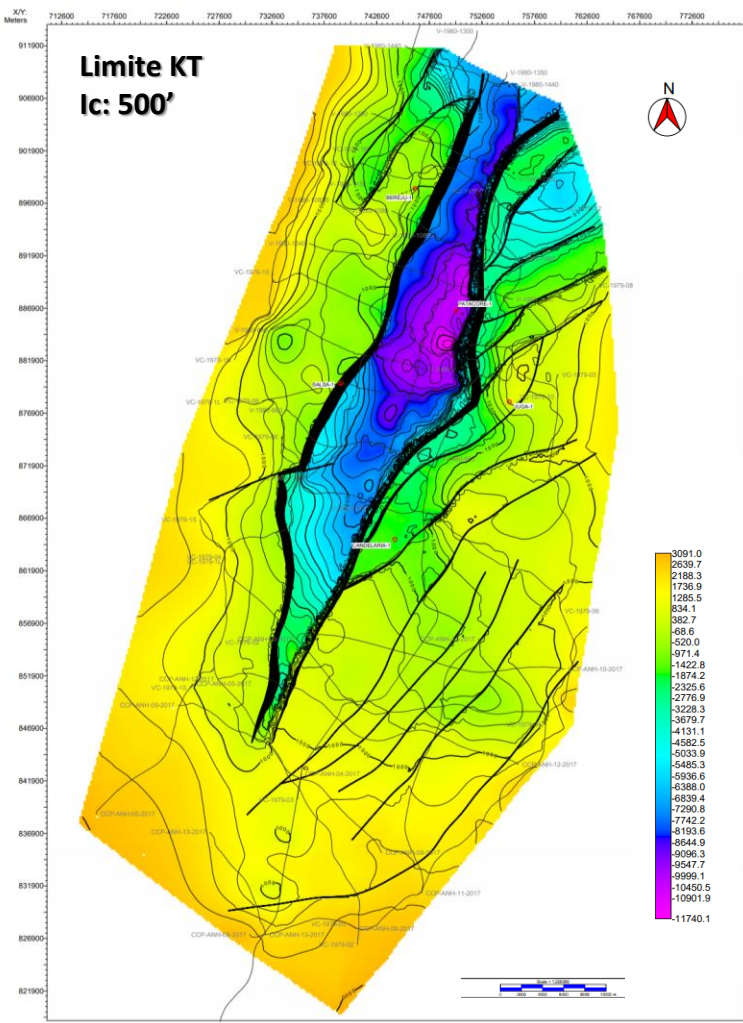


VC -1979-10

Pozo Juga-1
Proyectado 2.8 Km

SEISMIC INTERPRETATION

Depth maps - Central Zone

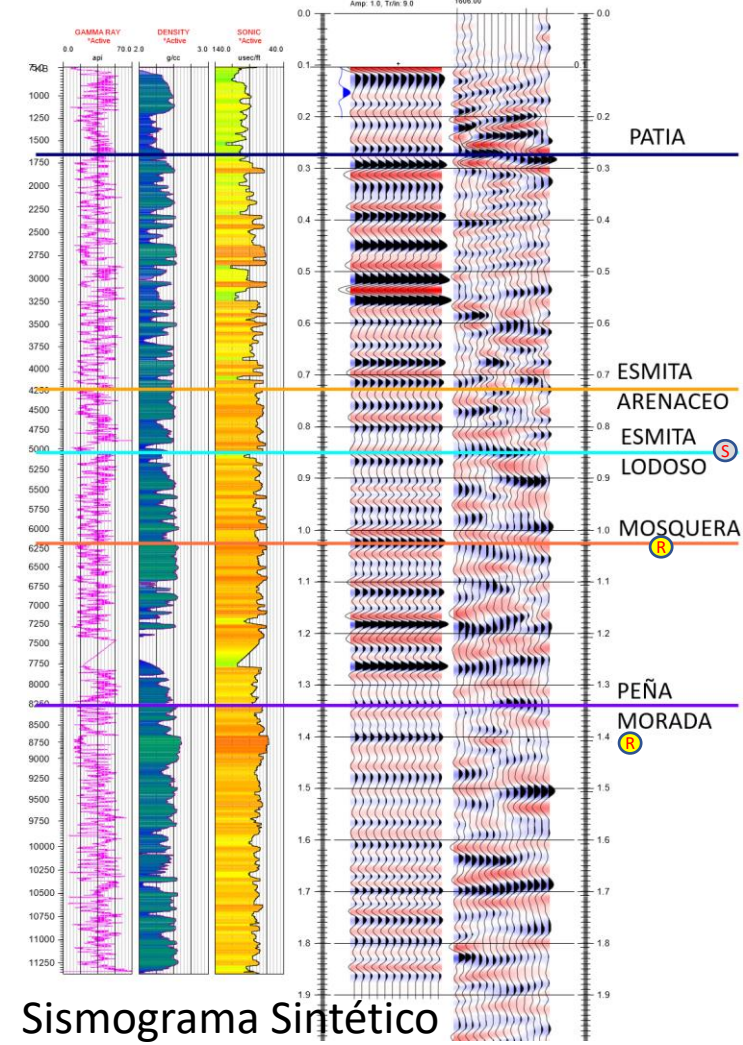


SEISMIC INTERPRETATION

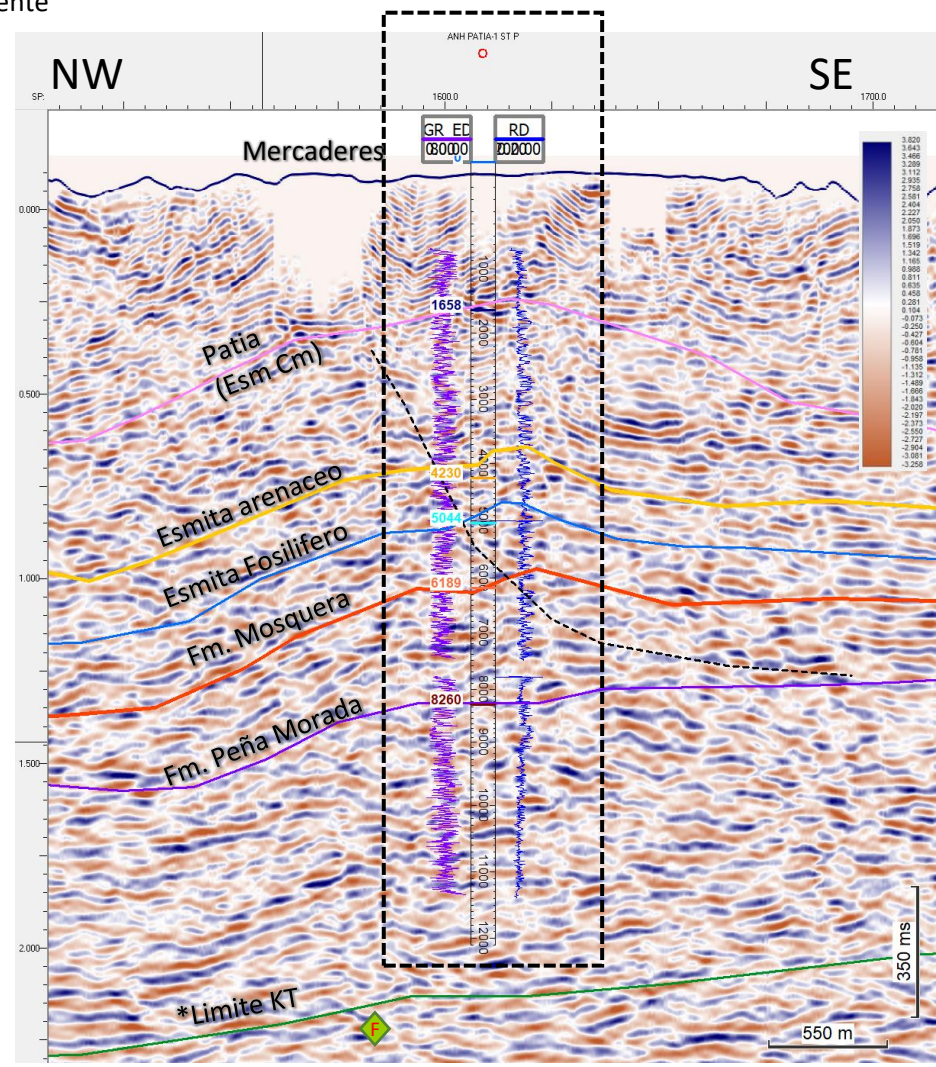
Well to seismic tie – South Zone

- S Sello
- R Reservorio
- D Roca fuente

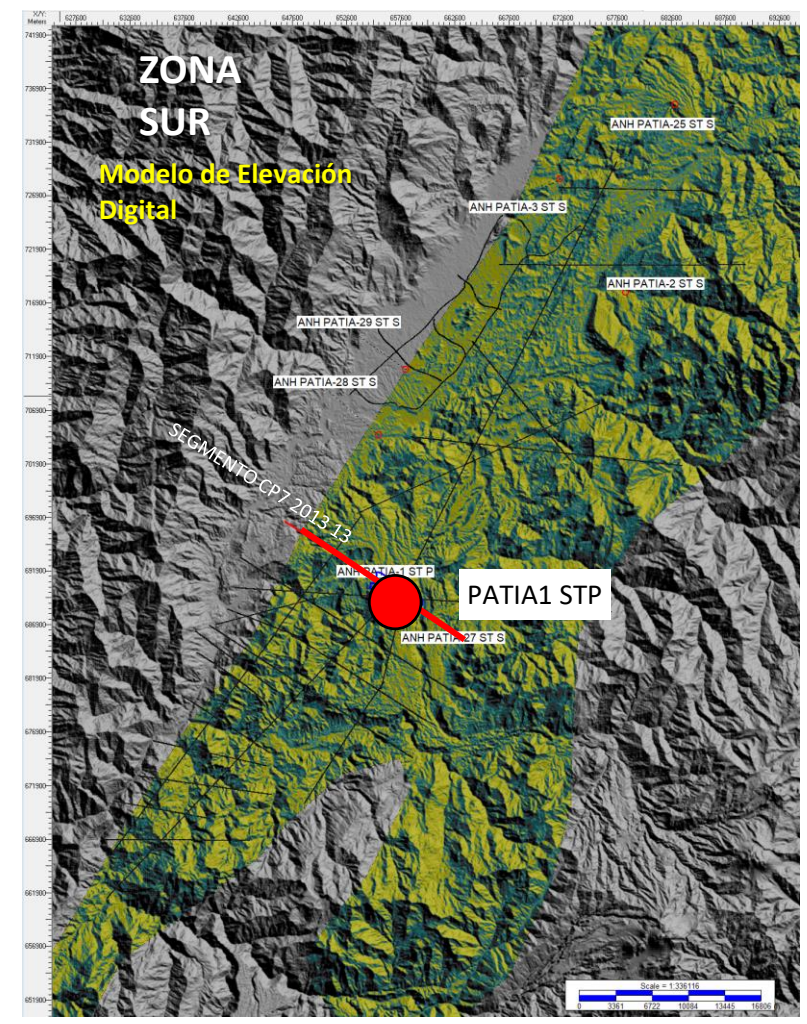
Pozo con registro de velocidades



Sismograma Sintético
Pozo Patia1stp TD: 12100'



Segmento de Linea sísmica CP7-2D-2013-12

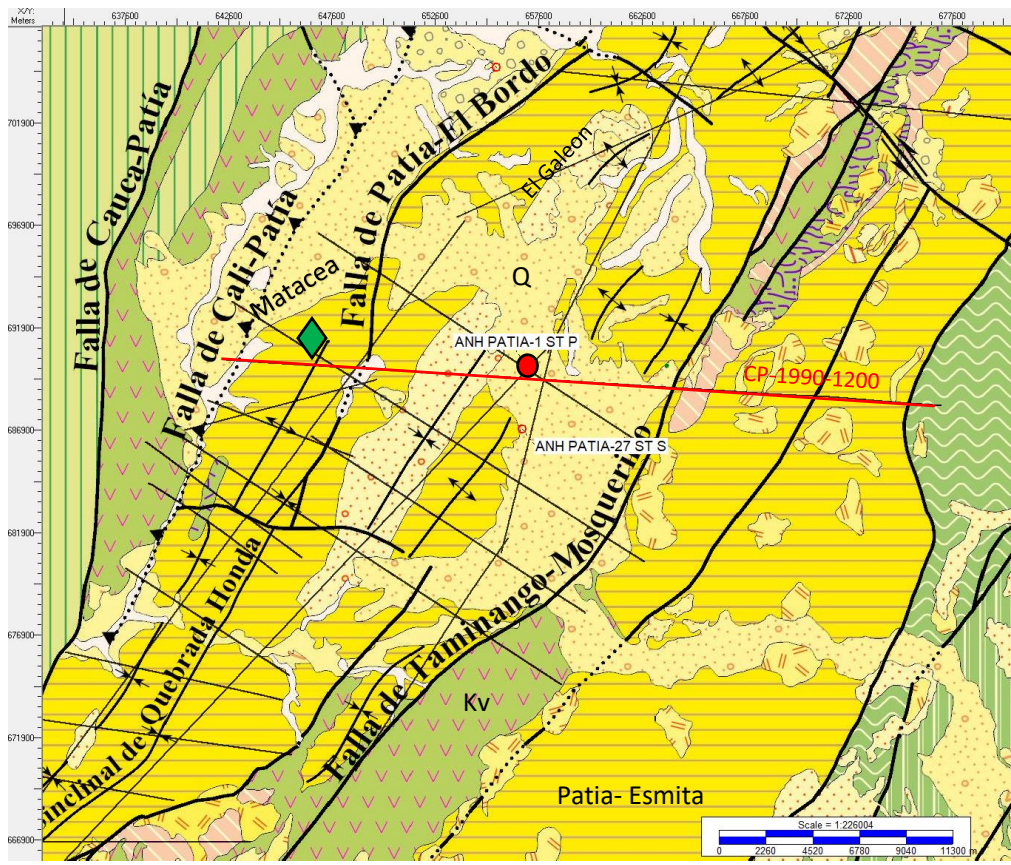


*Hipotético

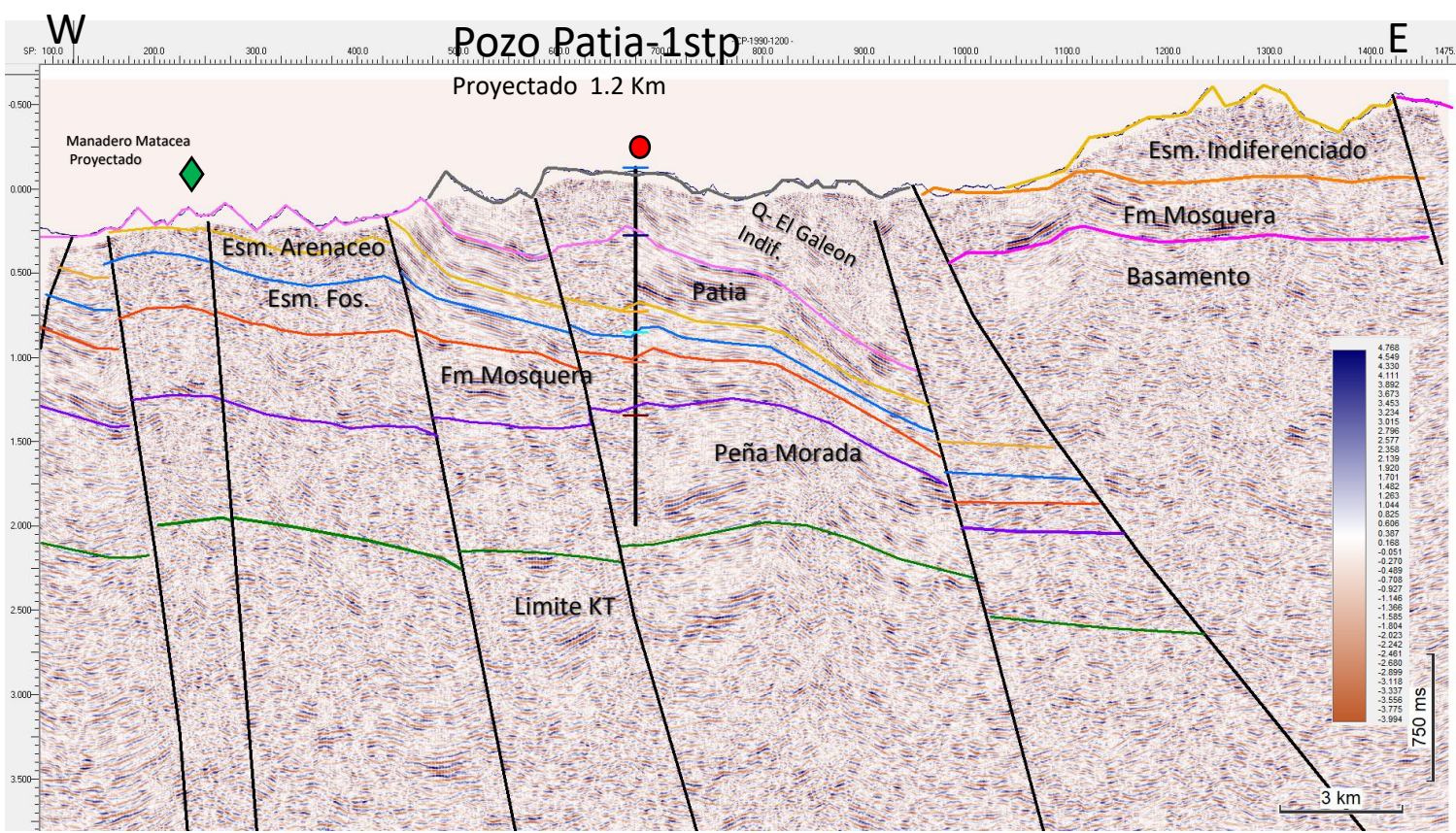
SEISMIC INTERPRETATION

Interpreted Seismic Markers - South Zone

Mapa Geológico 2015



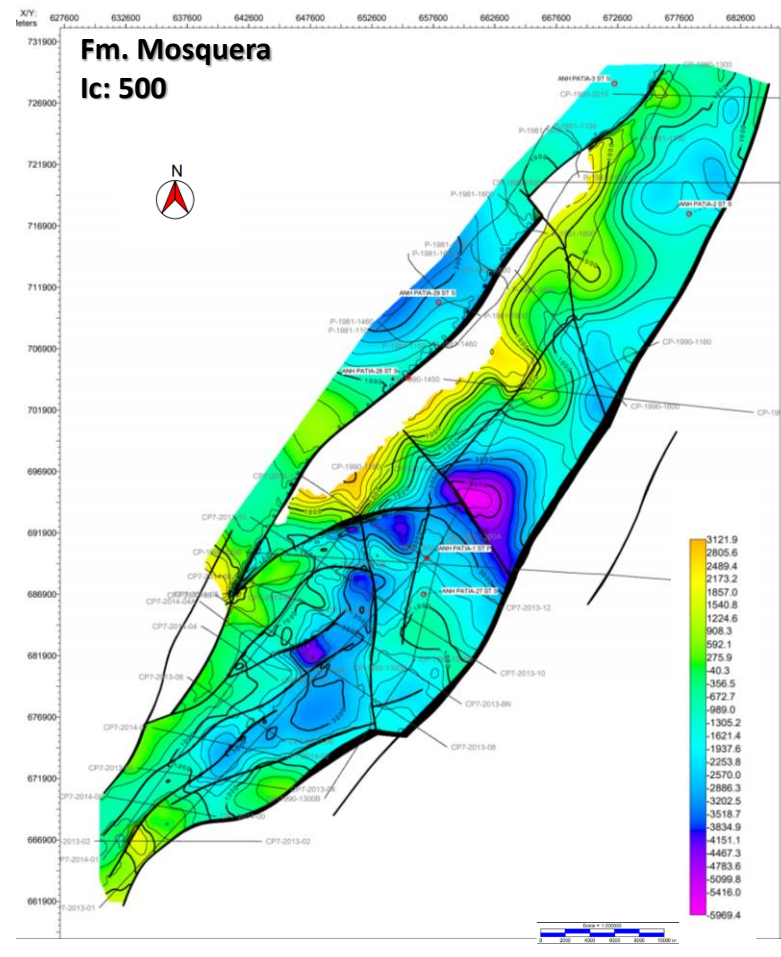
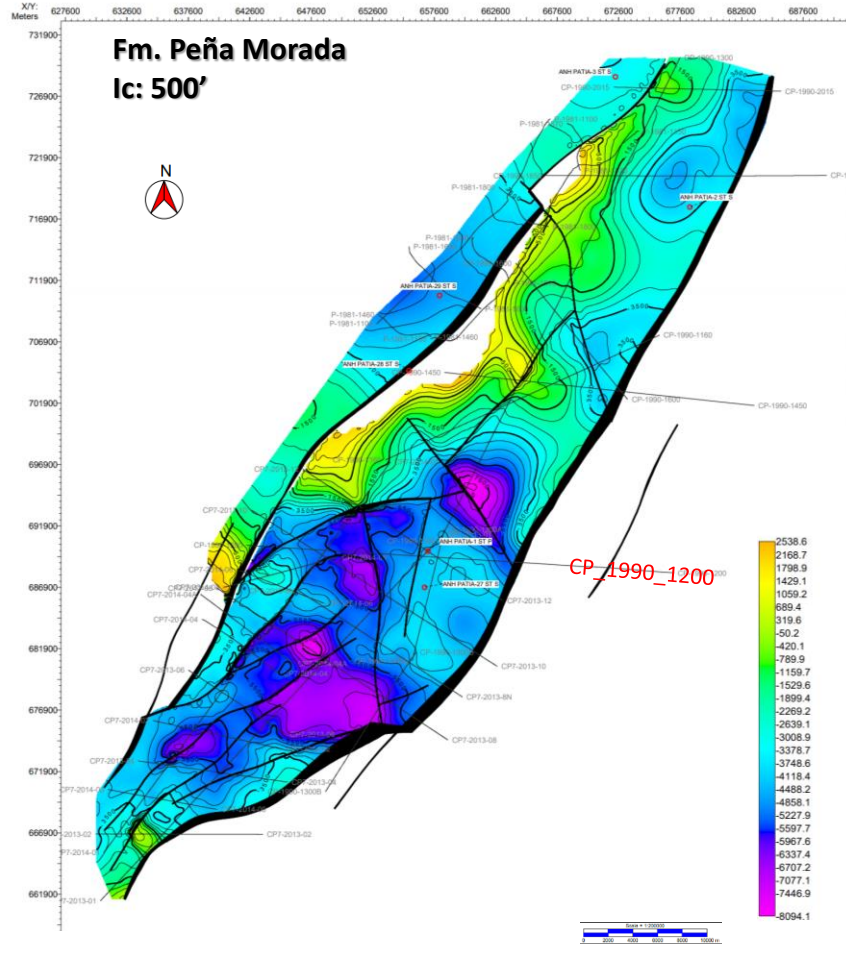
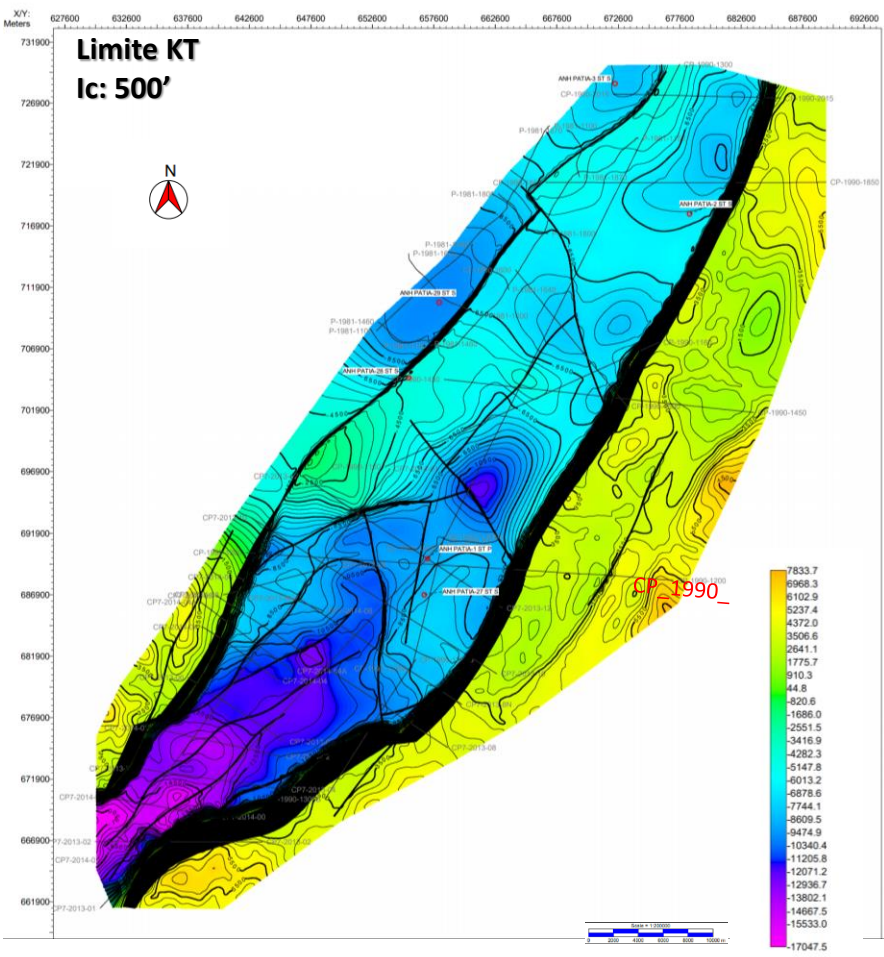
Manadero de aceite



CP-1990-1200

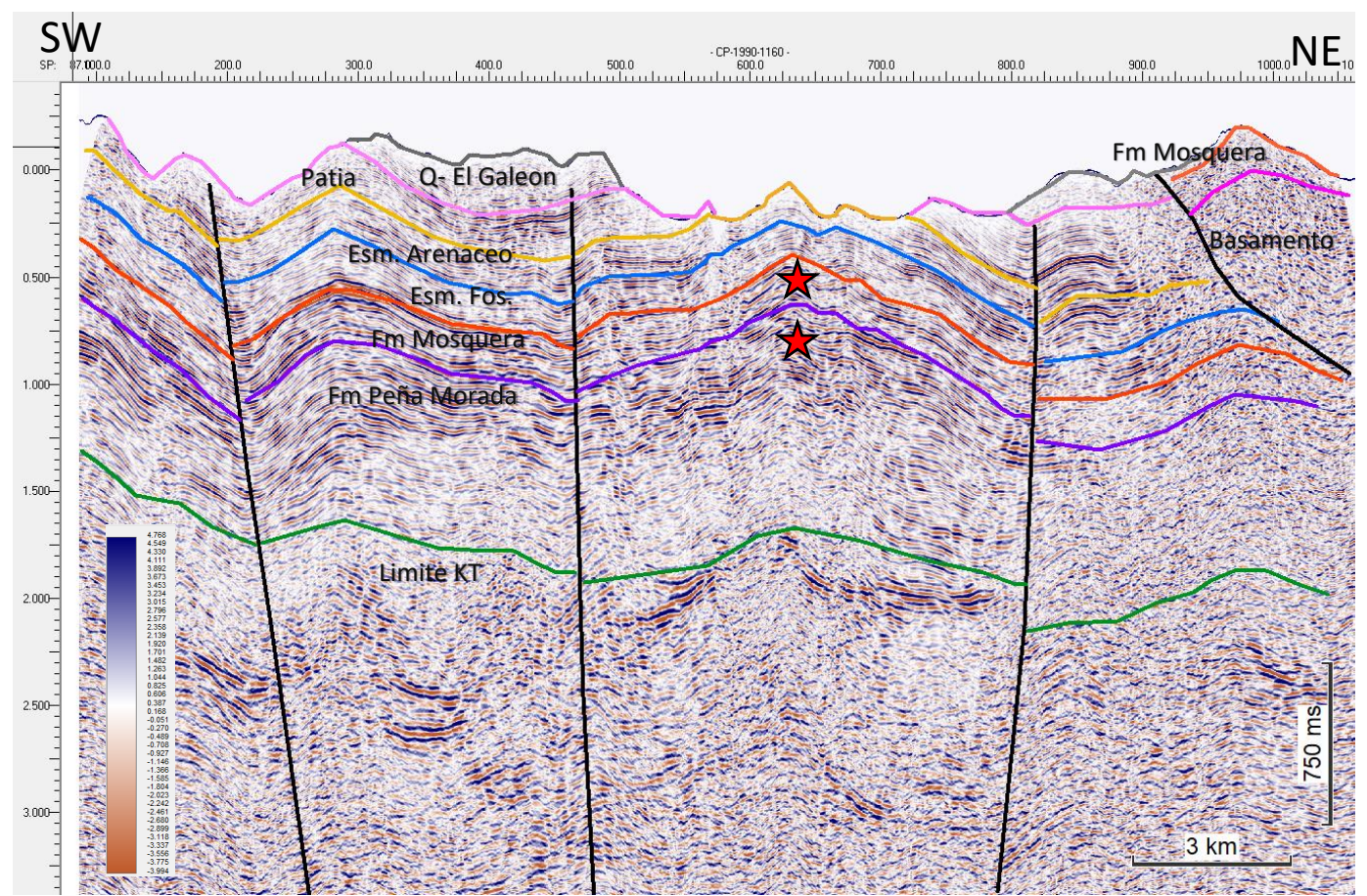
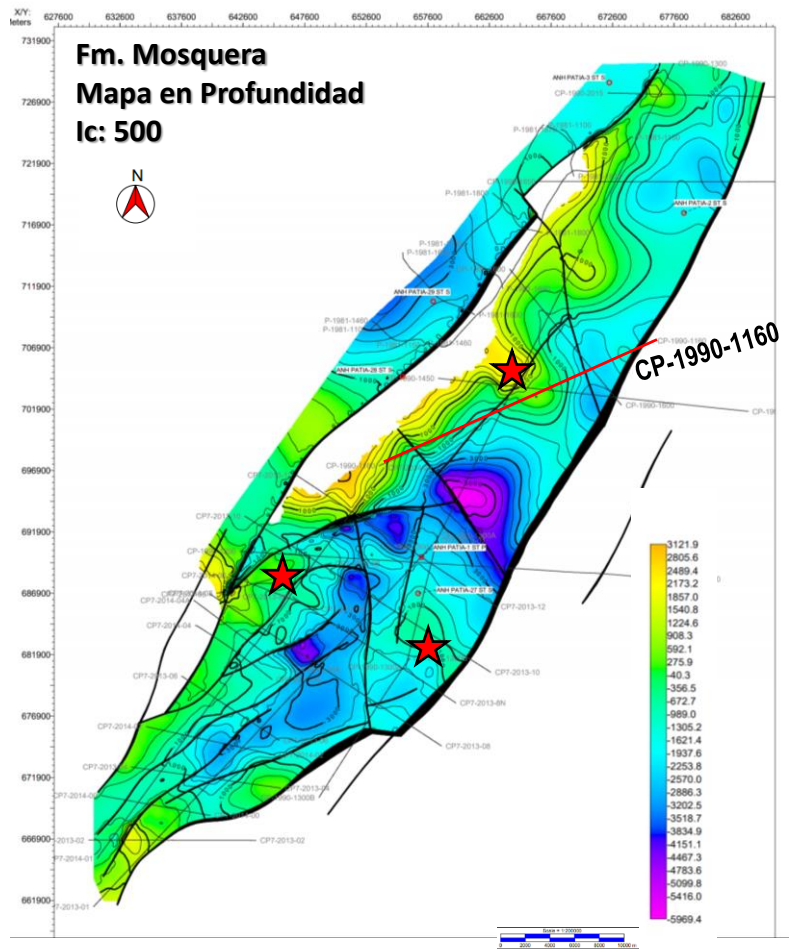
SEISMIC INTERPRETATION

Depth Maps - South Zone



SEISMIC INTERPRETATION

Seismic Markers and Probable Leads - South Zone



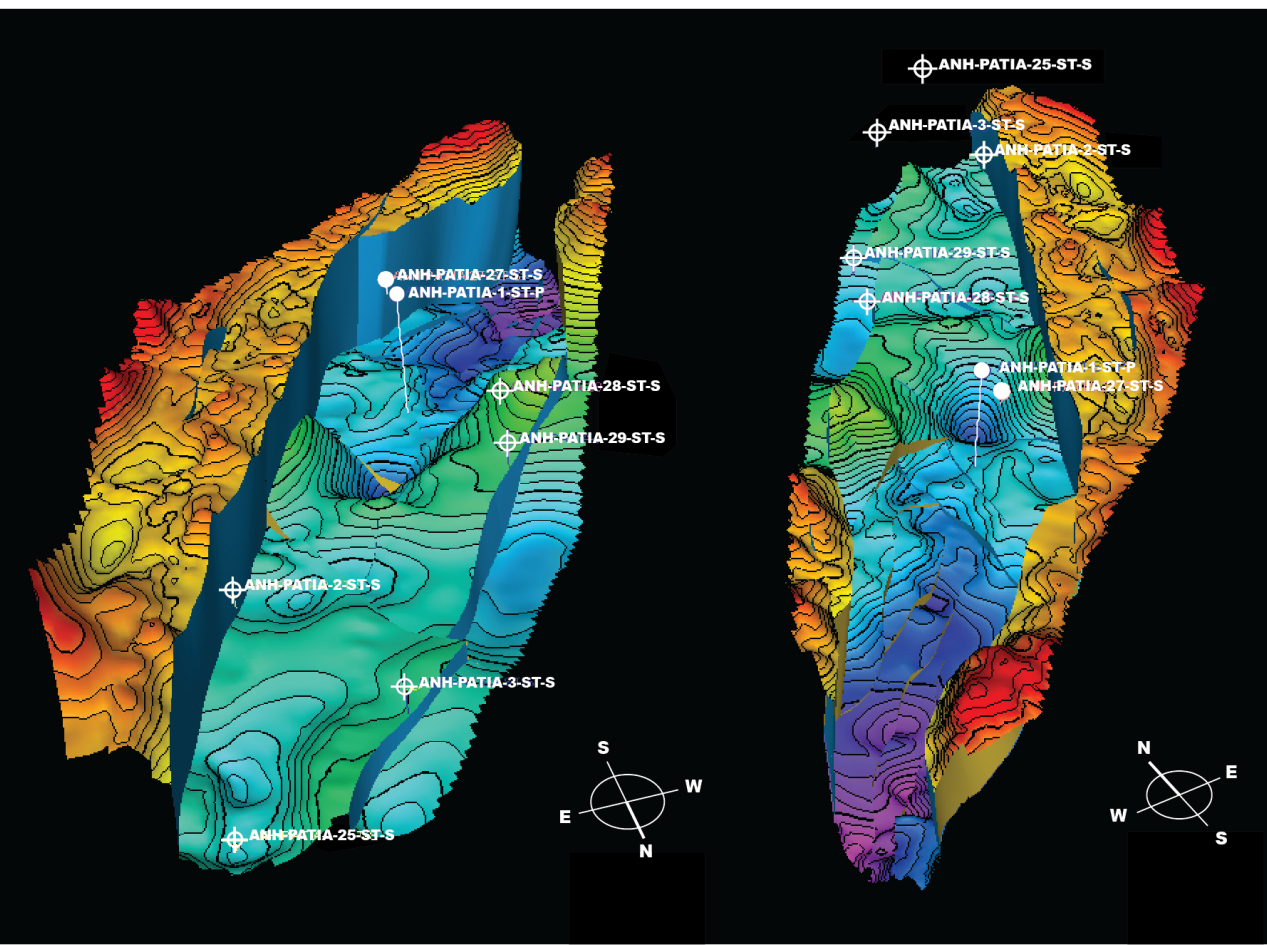
★ LEADS POTENCIALES

CP-1990-1160

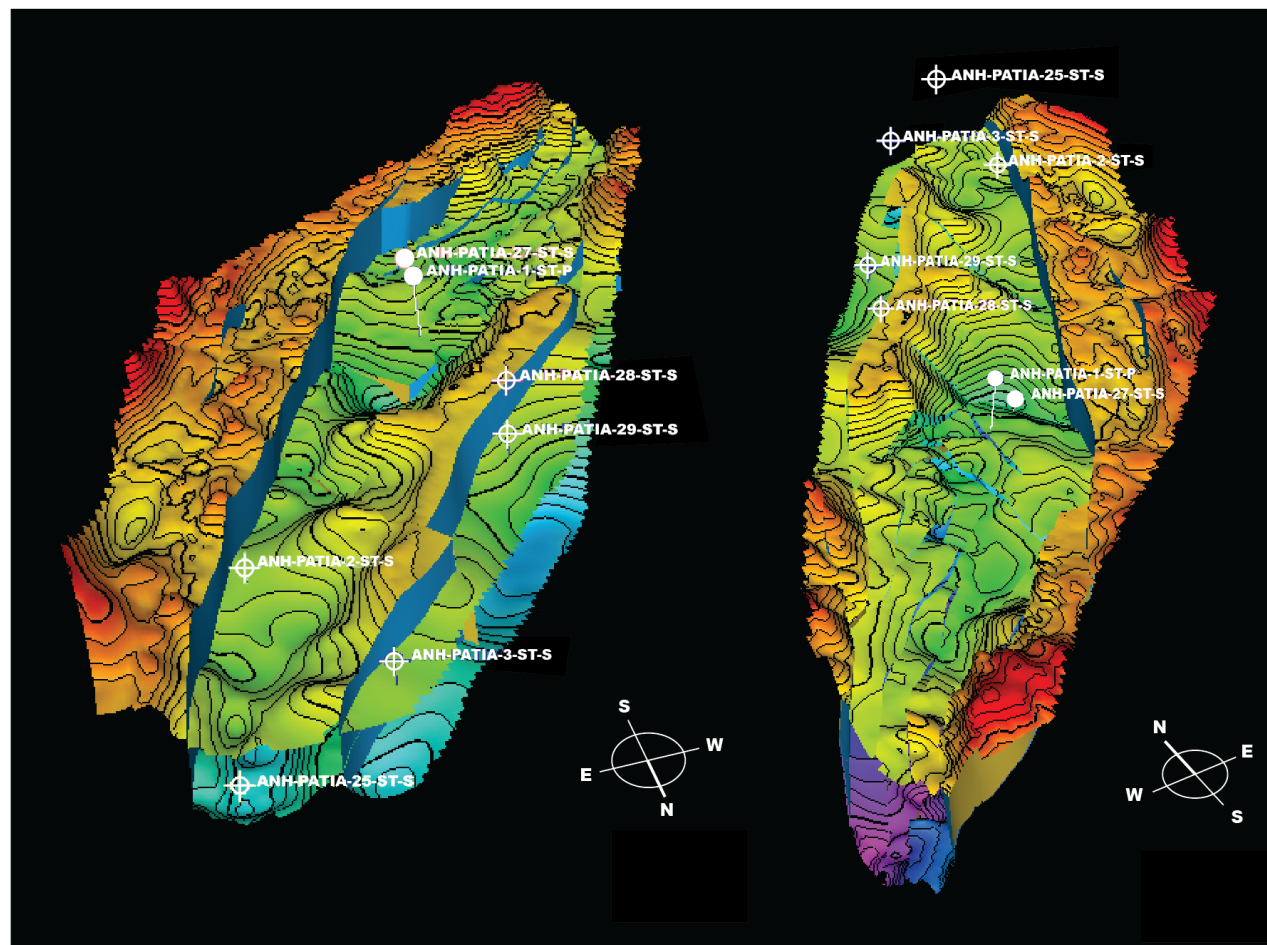
STRUCTURAL INTERPRETATION

Structural Geocellular Model - Subcuenca Cauca-Patía (South Zone)

SUBCUENCA PATIA MODELO ESTRUCTURAL NIVEL SUPERFICIE K-T

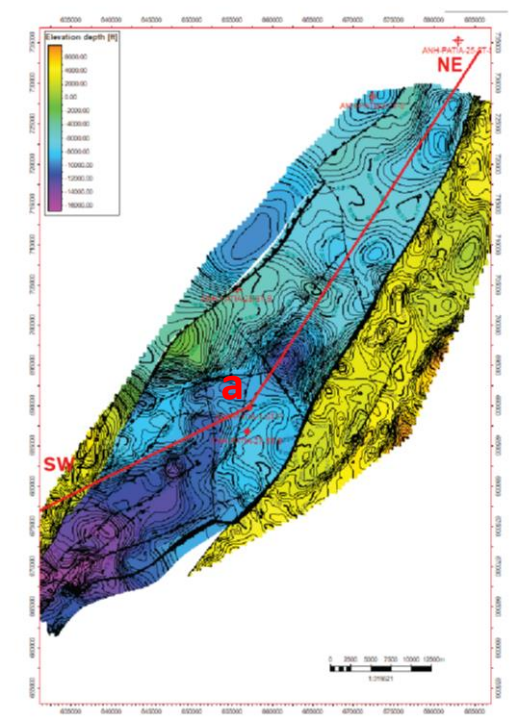
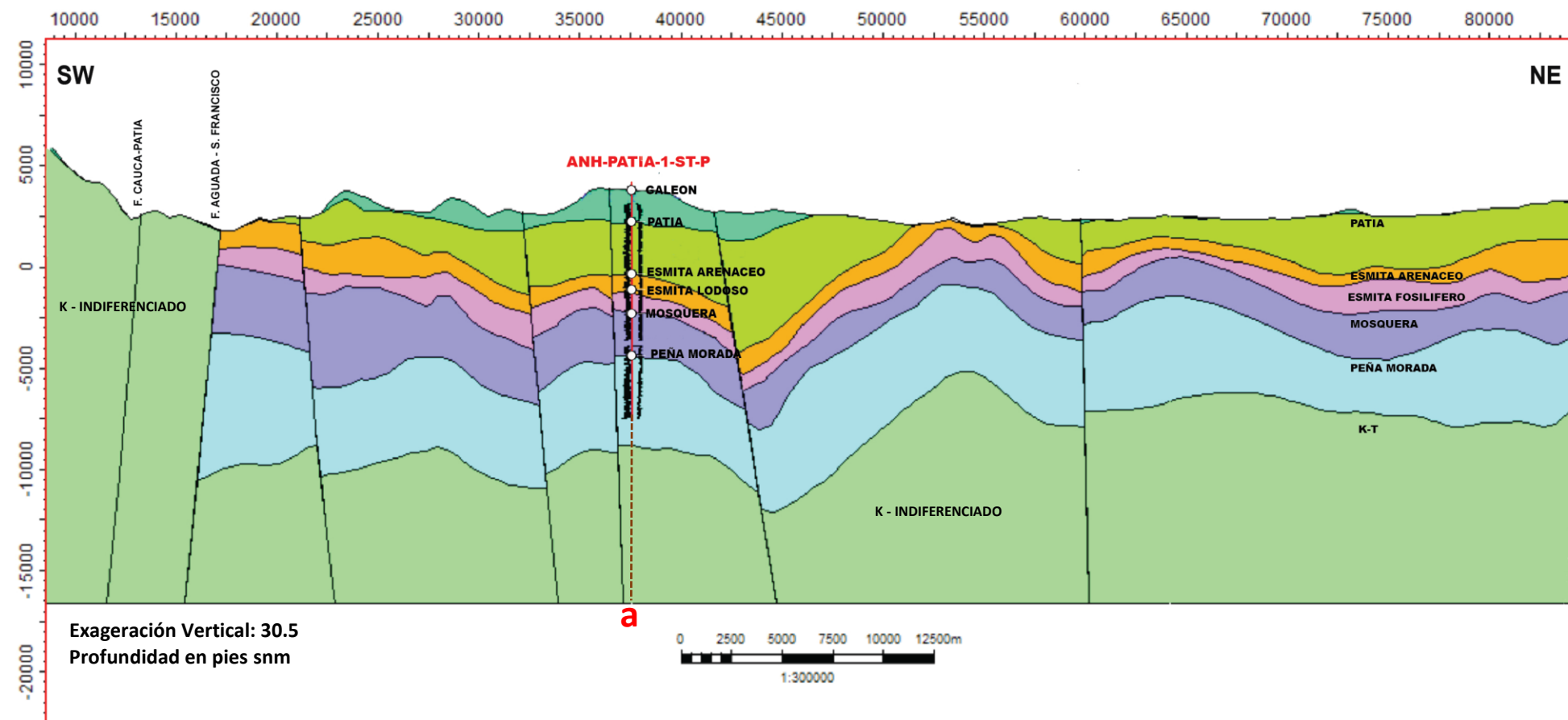


SUBCUENCA PATIA MODELO ESTRUCTURAL NIVEL SUPERFICIE MOSQUERA



STRUCTURAL INTERPRETATION

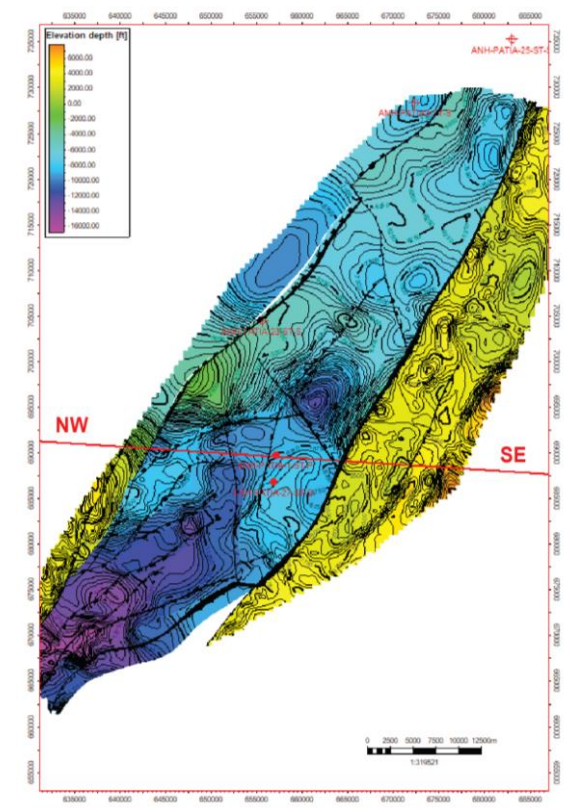
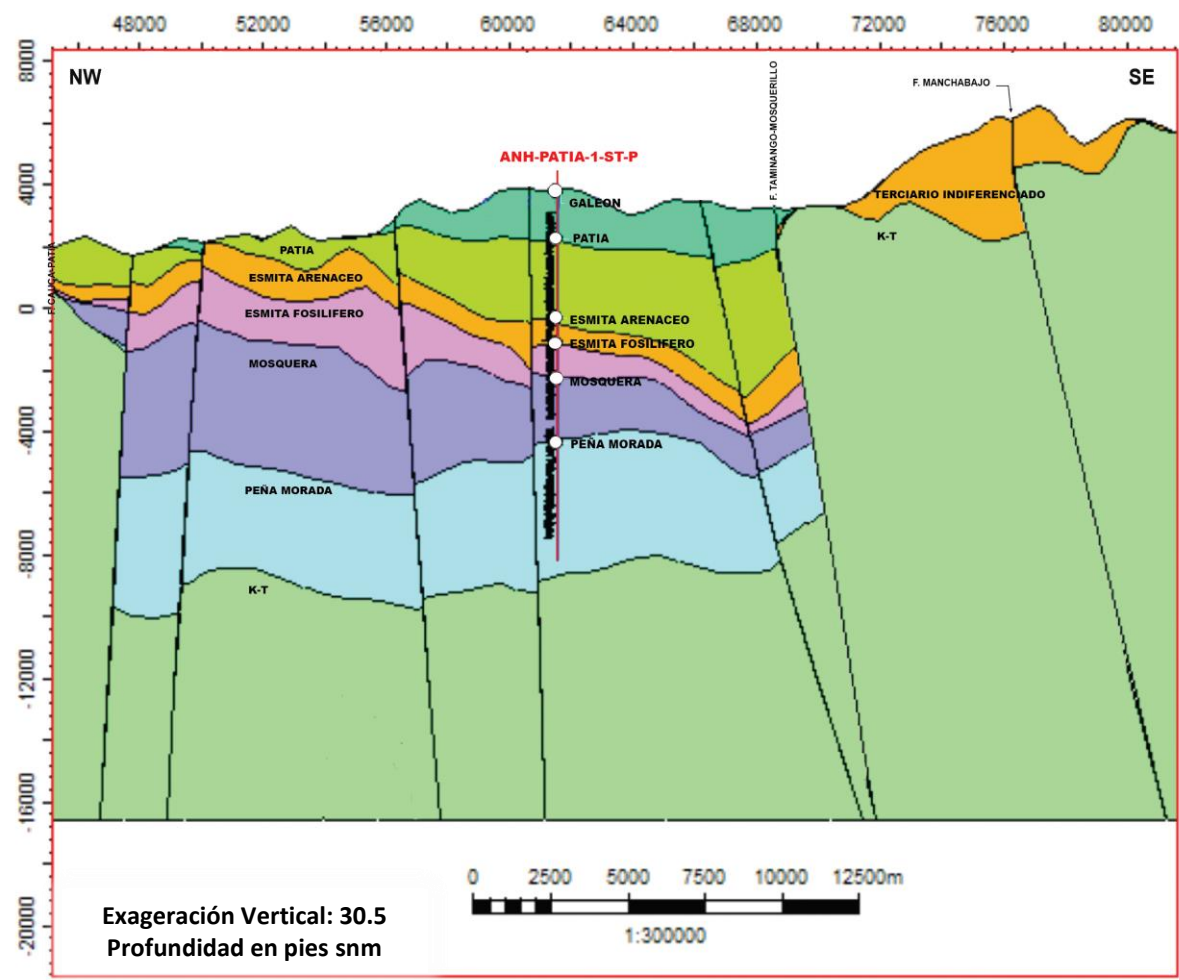
SW-NE Structural Cross Section - Sub-basin Cauca-Patía (South Zone)



Mapa Estructural al Límite K-T
Subcuenca Patía

STRUCTURAL INTERPRETATION

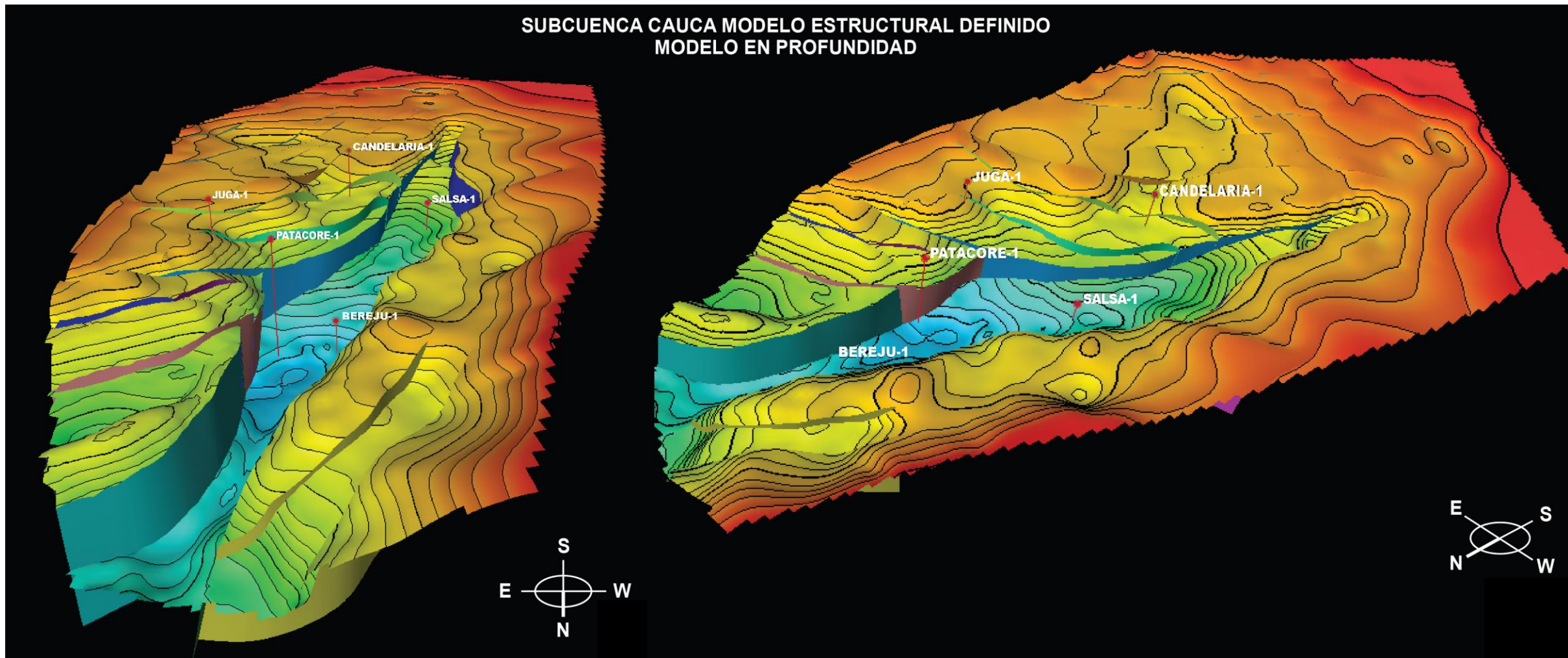
W-E Structural Cross Section - Sub-basin Cauca-Patía (South Zone)



Mapa Estructural al Limite K-T
Subcuenca Patía

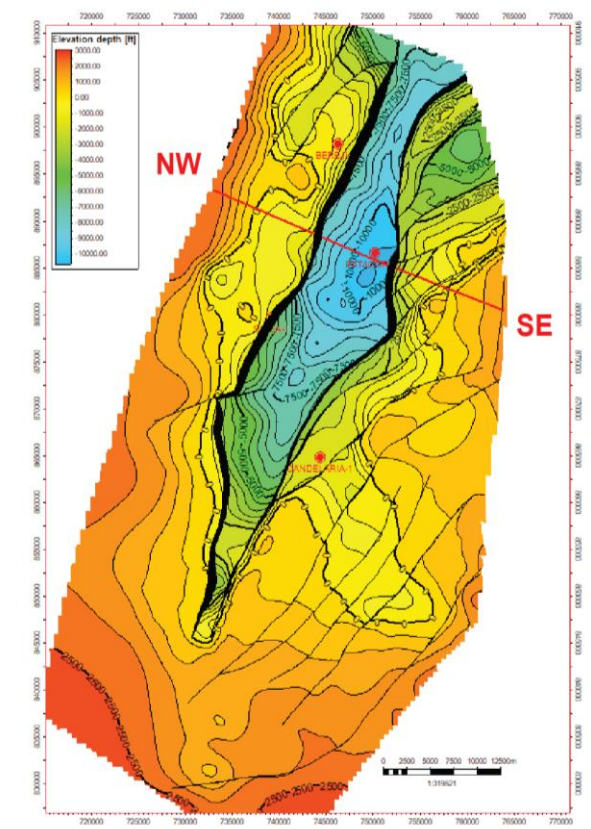
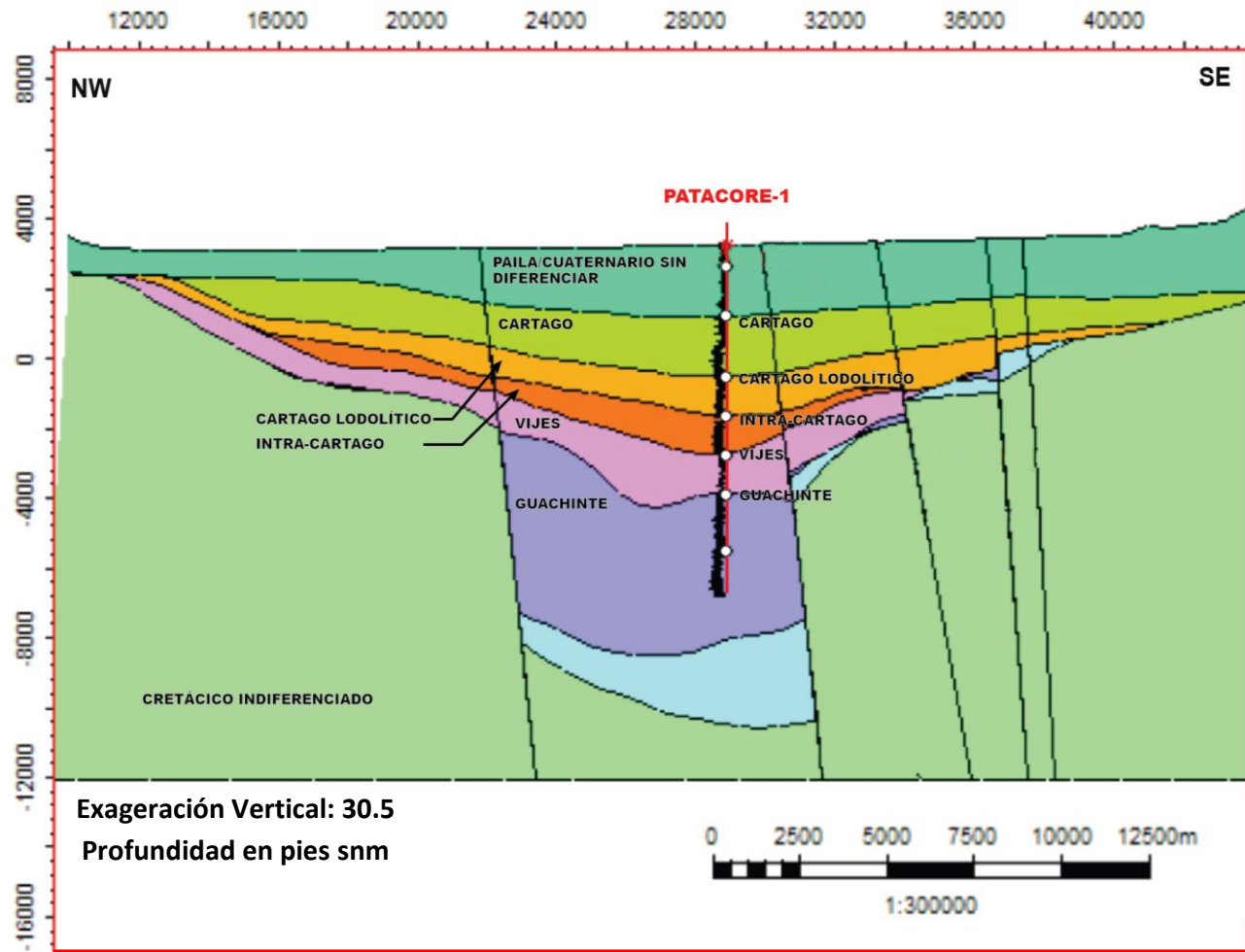
STRUCTURAL INTERPRETATION

Geometric Structural Model – Cauca Sub-basin (Central Zone)



STRUCTURAL INTERPRETATION

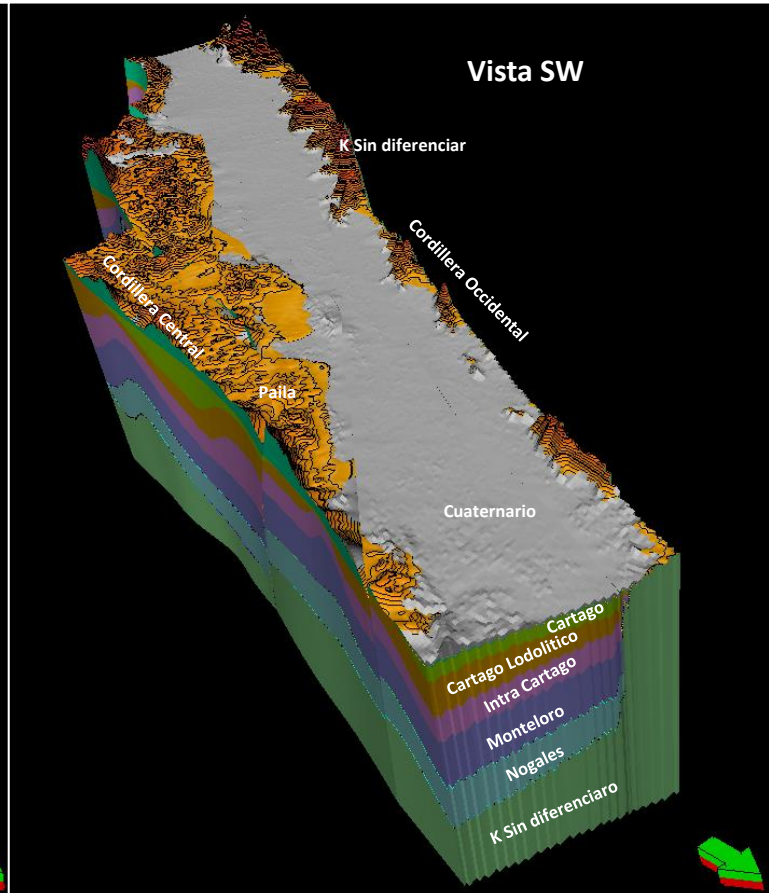
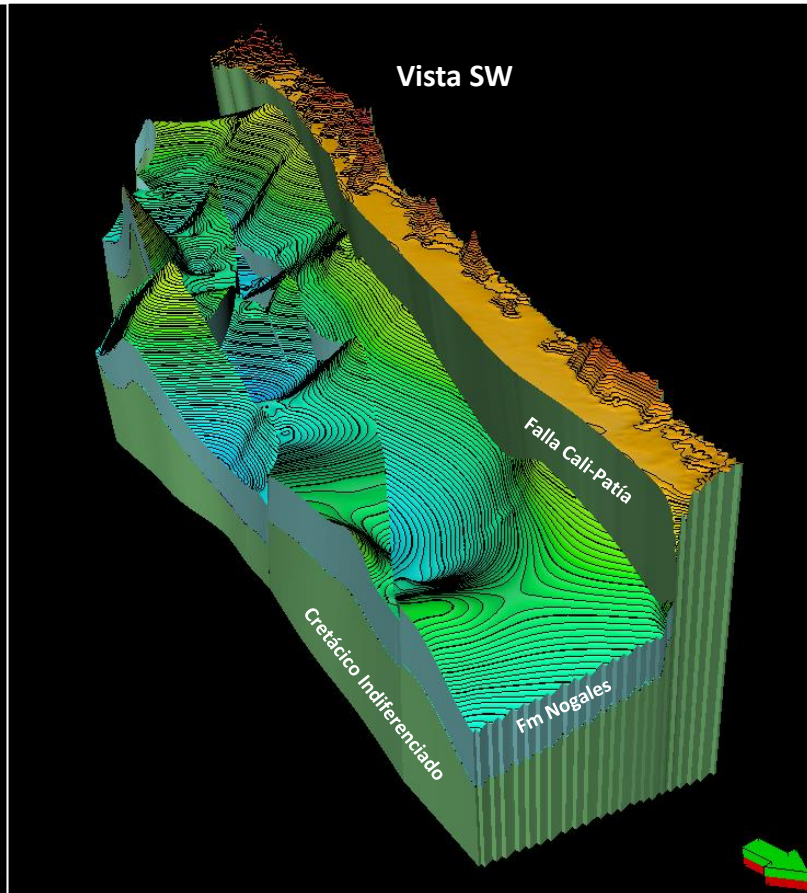
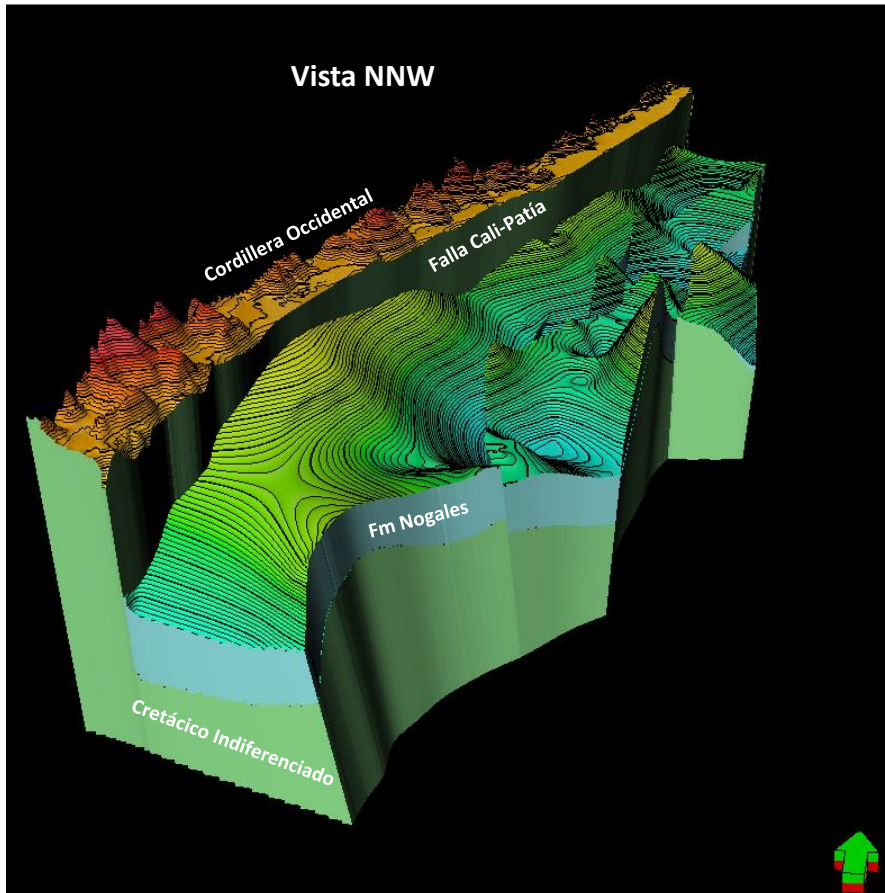
NW-SE Structural Cross Section – Cauca sub-basin Cauca (Central Zone)



Mapa Estructural al Limite K-T
Subcuenca Cauca

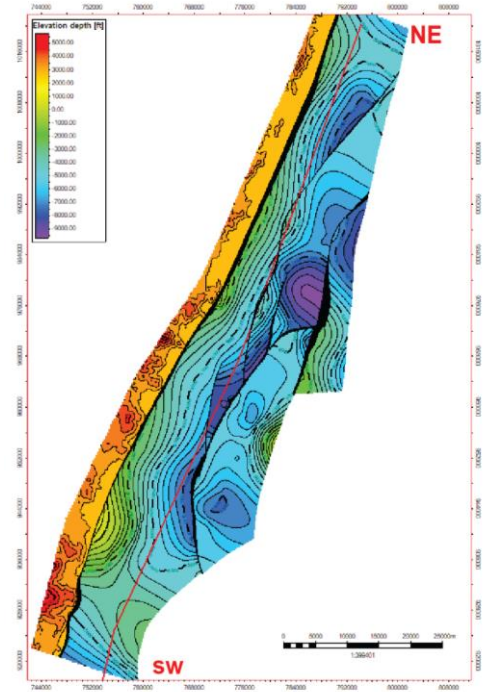
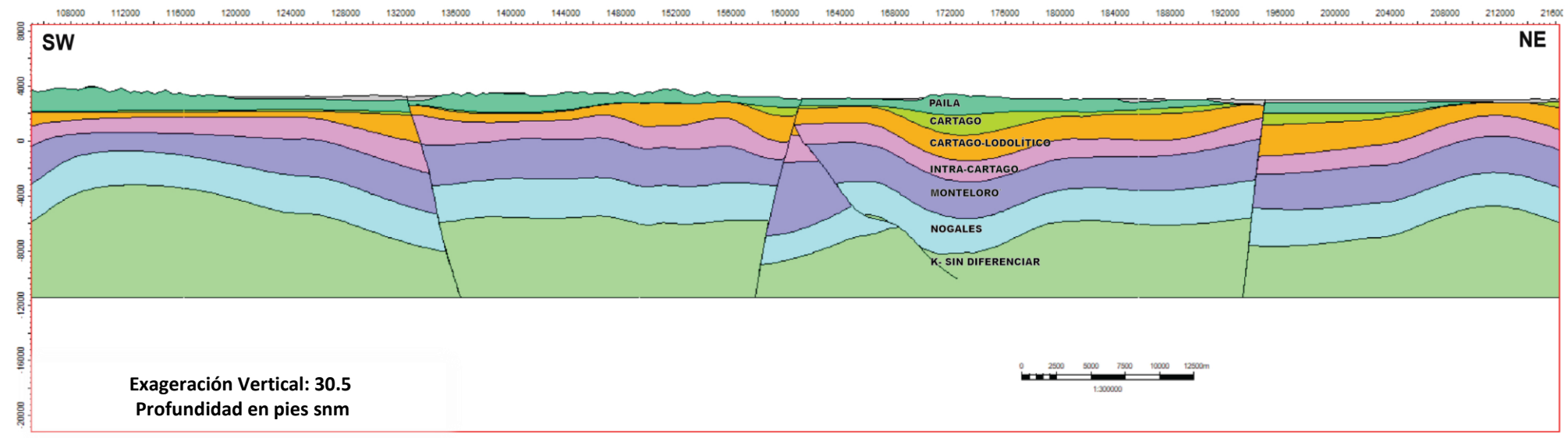
STRUCTURAL INTERPRETATION

3D Block Diagrams Geocellular Model - North Zone



STRUCTURAL INTERPRETATION

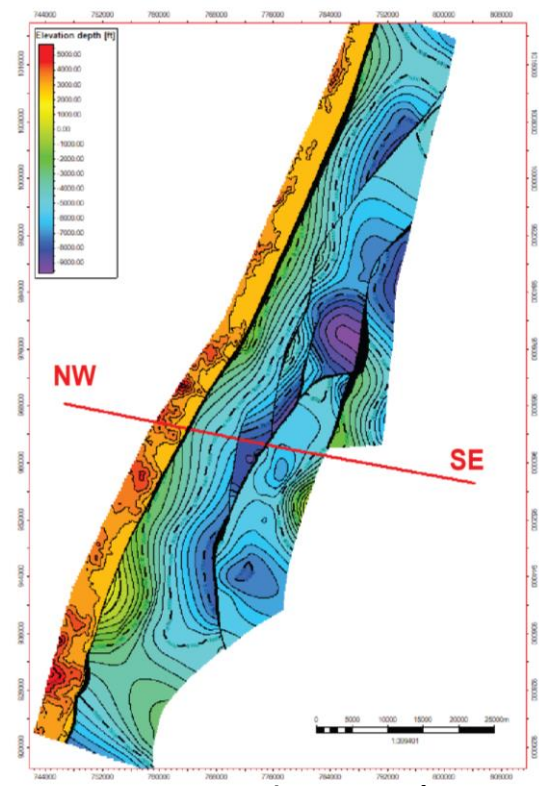
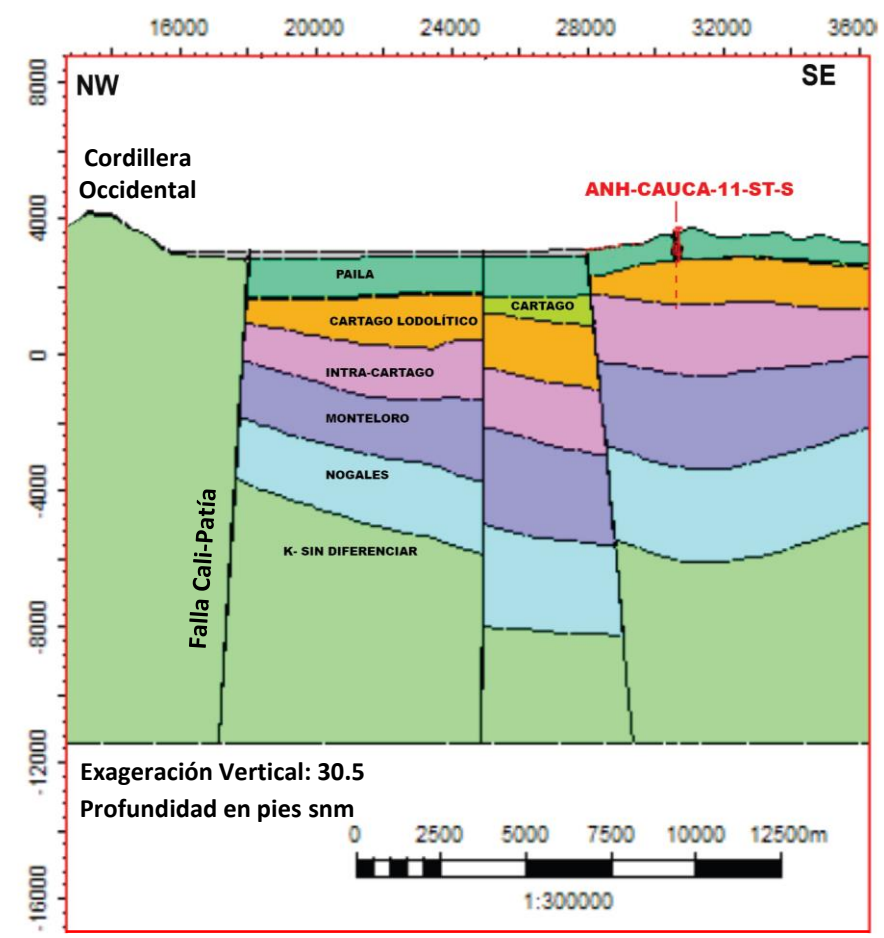
SW-NE Structural Cross Section - North Zone



Mapa estructural Topo Cretácico Indiferenciado – Subcuenca Cauca

STRUCTURAL INTERPRETATION

NW-SE Structural Cross Section - North Zone



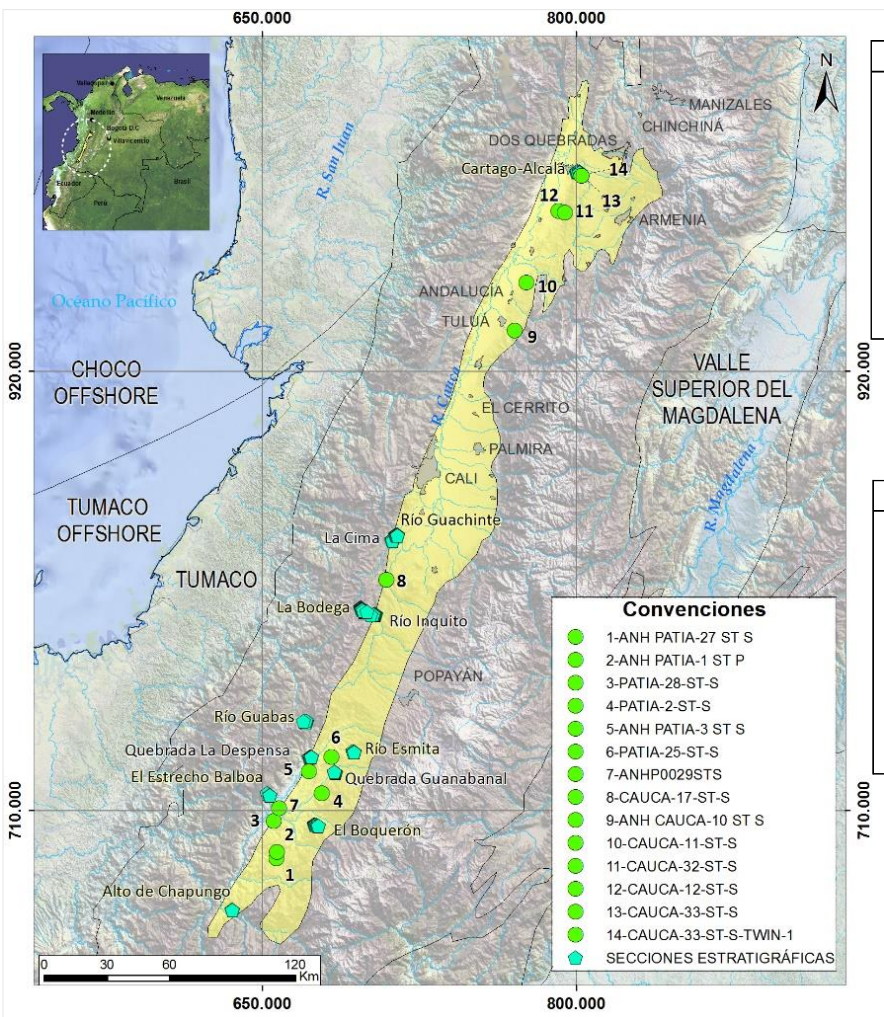
Mapa Estructural Tope Cretácico Indiferenciado - Subcuenca Cauca

Modeling of Petroleum Systems & Play Fairways Cauca-Patía Basin

ROCK GEOCHEMISTRY

Geochemical data - Statistics of well and outcrop samples

Geochemical Statistics Samples of 16 Outcrops



Afloramiento	Estadística descriptiva y de tendencia media de datos											
 TOTAL 	COT (%) TOC (%)	S ₁	S ₂	S ₃	TMAX	IH	IO	IP (S ₁ /S ₁ +S ₂)	PG (S ₁ +S ₂)	S1/COT	Reflectancia de la Vitrinita	
	CANTIDAD DATOS	226	182	146	182	163	182	182	182	182	182	62
	MAXIMO	55,33	2,56	155,89	19,35	542	470	366	1,00	157,39	0,78	1,86
	CUARTIL 3	3,28	0,46	8,46	1,32	447	173	55	0,38	7,19	0,16	0,64
	MEDIANA	1,57	0,19	3,09	0,52	436	98	25	0,10	2,24	0,09	0,54
	MEDIA	3,63	0,37	8,73	1,61	443	114	40	0,30	7,37	0,13	0,64
	CUARTIL 1	0,57	0,09	1,09	0,24	428	26	12	0,04	0,50	0,05	0,49
MINIMO	0,02	0,02	0,23	0,02	404		3	0,01	0,02	0,01	0,42	

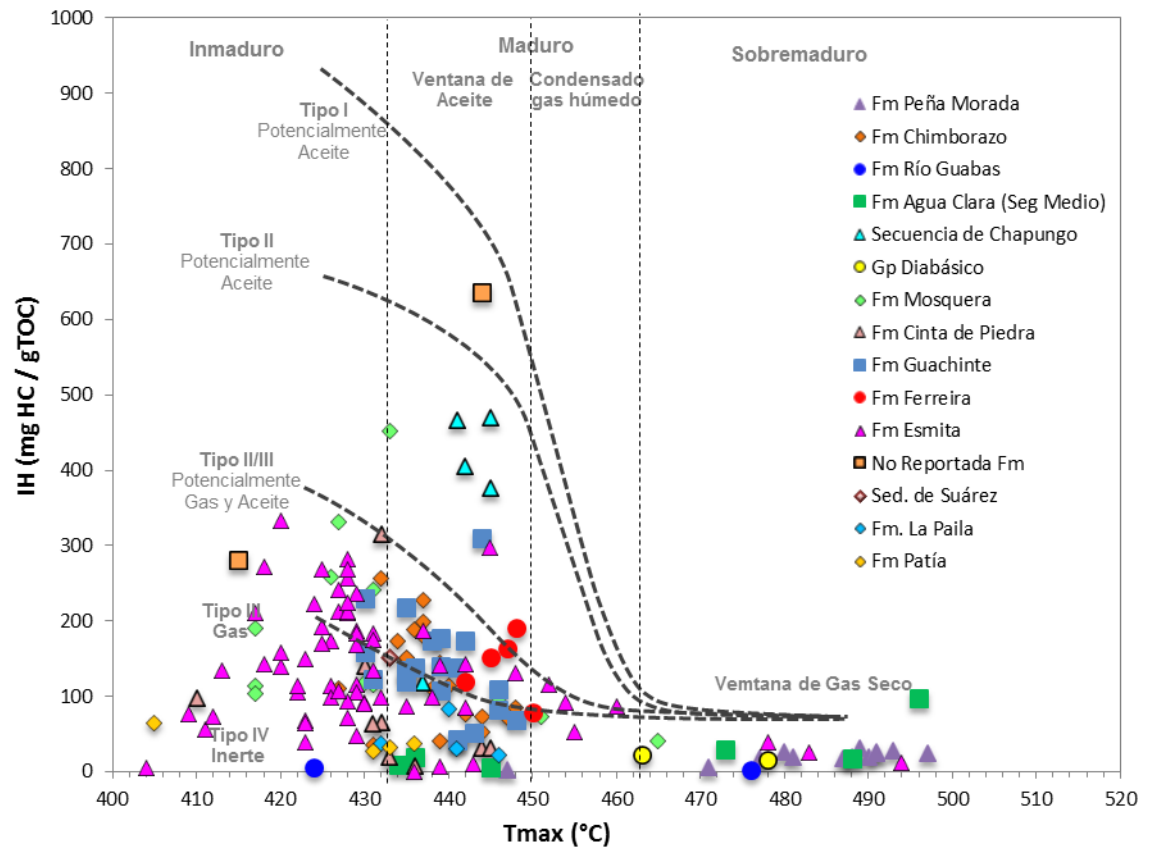
Geochemical Statistics Samples from 14 Wells

Pozos	Estadística descriptiva y de tendencia media de datos											
 TOTAL 	COT (%) TOC (%)	S ₁	S ₂	S ₃	TMAX	IH	IO	IP (S ₁ /S ₁ +S ₂)	PG (S ₁ +S ₂)	S1/COT	Reflectancia de la Vitrinita	
	CANTIDAD DATOS	44	24	24	21	23	24	24	24	24	24	18
	MAXIMO	4,46	0,30	27,46	2,91	446,00	637,00	283,00	0,67	27,49	0,23	0,65
	CUARTIL 3	0,85	0,10	0,55	0,70	440	39	71	0,53	0,62	0,13	0,41
	MEDIANA	0,54	0,06	0,17	0,16	431	29	32	0,20	0,22	0,08	0,30
	MEDIA	0,96	0,07	1,59	0,62	395	60	58	0,29	1,66	0,09	0,32
	CUARTIL 1	0,30	0,03	0,07	0,05	331	10	7	0,10	0,14	0,04	0,21
MINIMO	0,15	0,02	0,01	0,03	295		5	0,00	0,03	0,01	0,17	

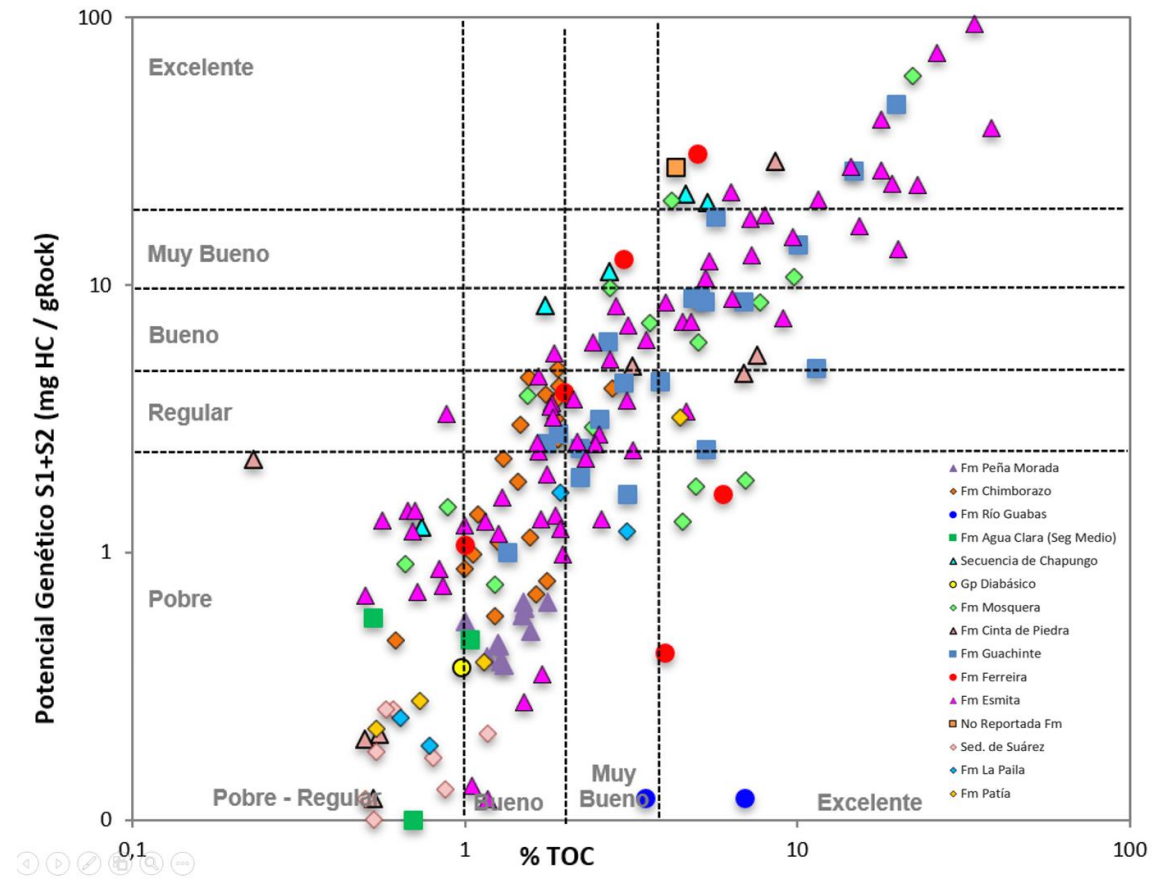
- RockEval geochemical data and Vitrinite reflectance
- Most wells only have Samples from the Miocene and Quaternary
- Outcrop sections contain K and T sediments

ROCK GEOCHEMISTRY

Thermal maturity and early generation phase



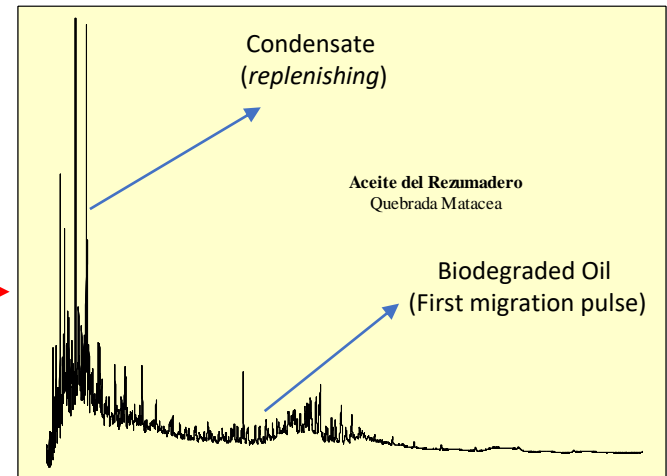
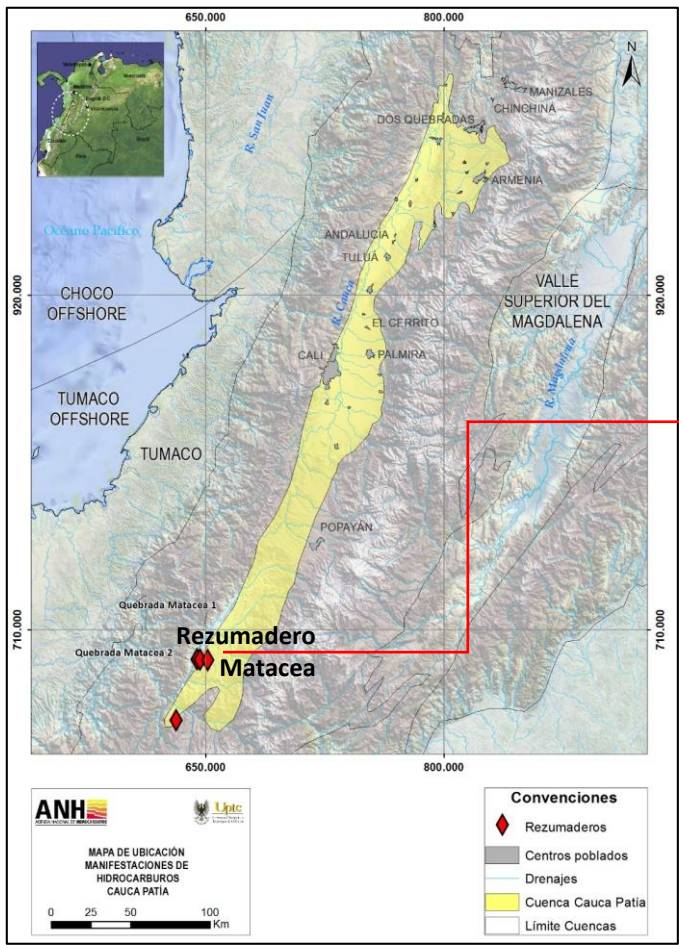
- High concentration of Kerogen Type II and IV
- Notorious Kerogeno Type II for Chapungo Sequence
- Very high Tmax values (Unreliable due to low S2 values)



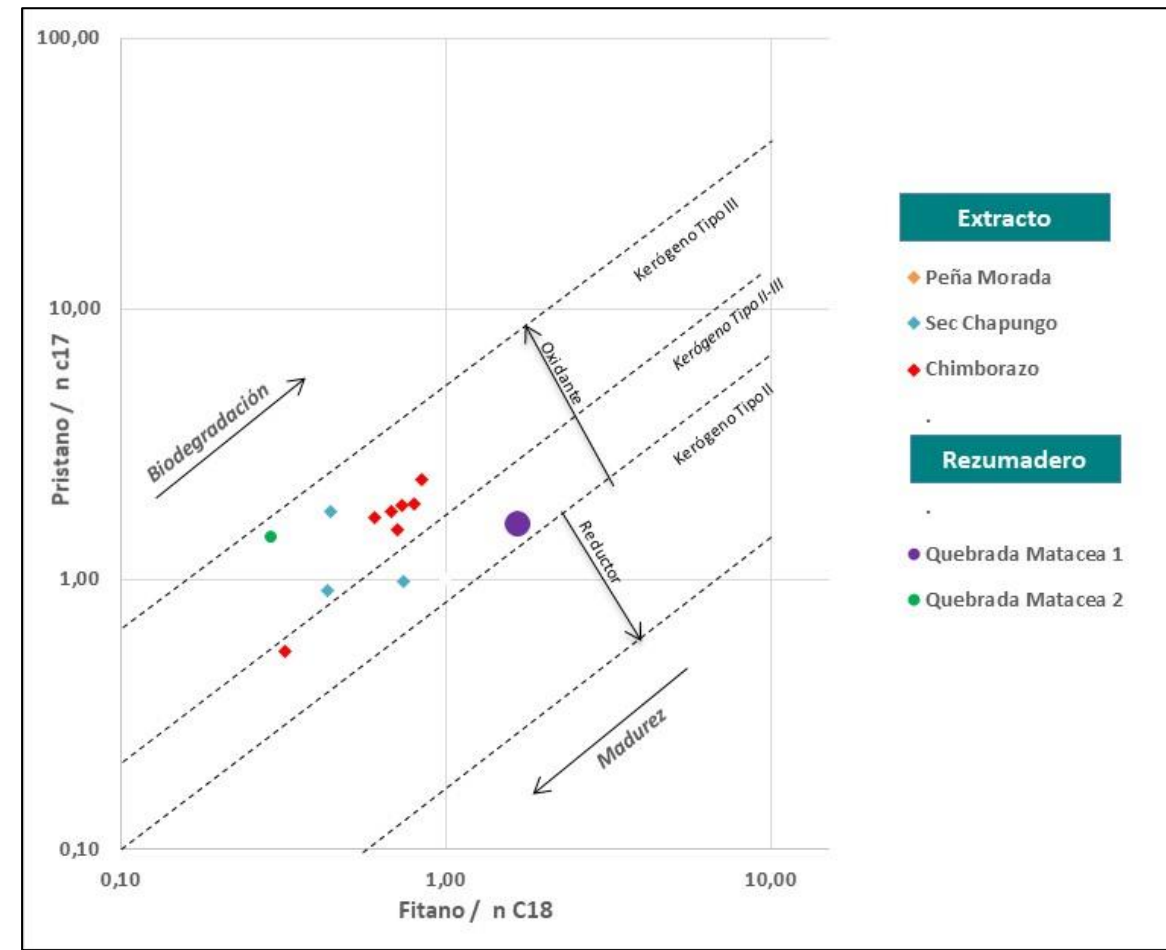
- Wide range in generating potential
- Notorious dispersion from good to excellent (outcrop samples) in the Esmita Formation

GEOCHEMISTRY OF CRUDE OIL

Matacea - biodegraded crude with evidence condensate replenish



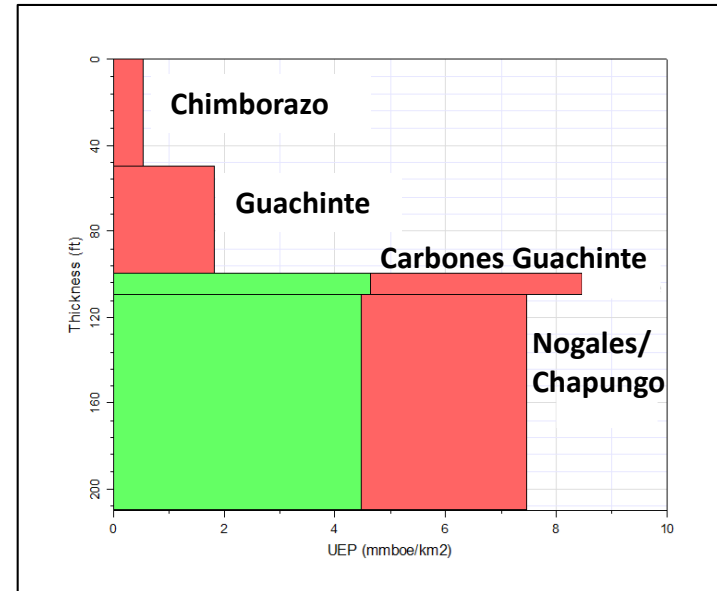
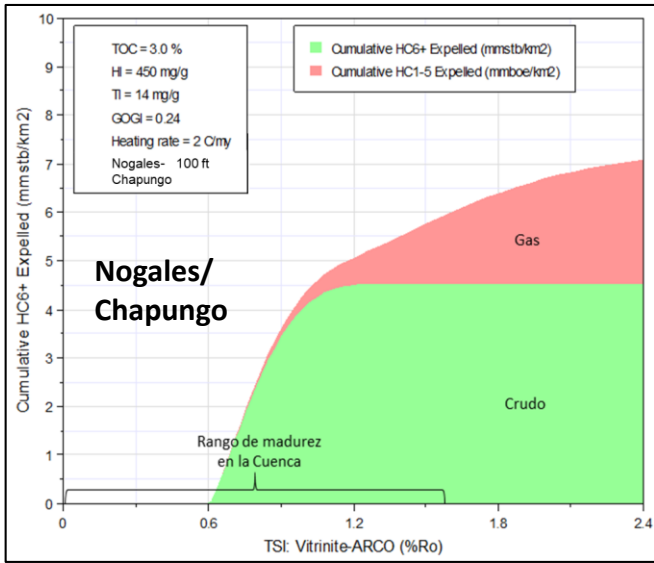
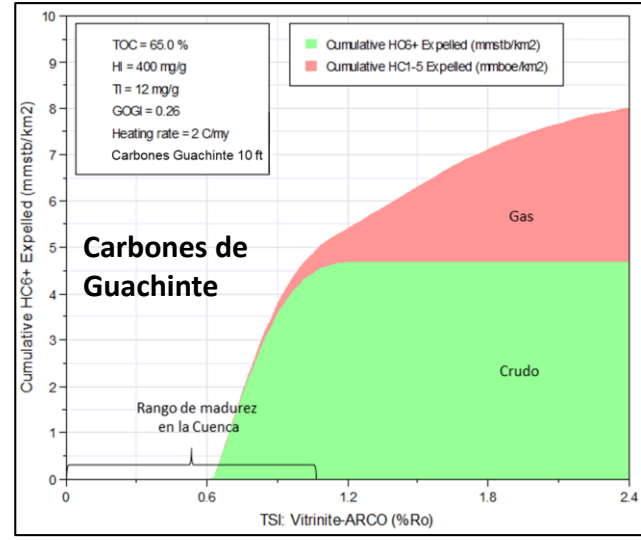
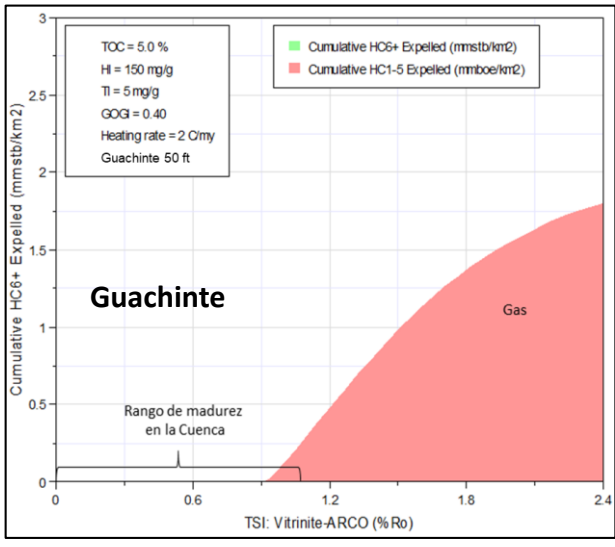
Oil chromatogram of the Quebrada Matacea seep Mixture between biodegraded crude oil and recharging with fresh condensate



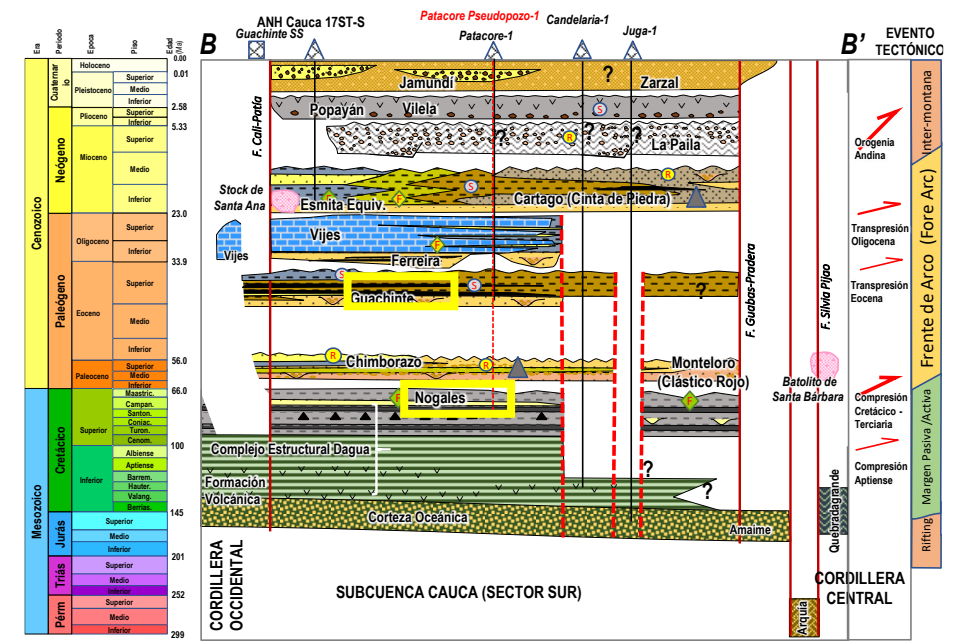
Biomarkers indicate organic facies of proximal tertiary marine environments (presence of Oleanane). At least two generating intervals reached expulsion level with thermal maturity compatible with the end of the oil window.

KINETICS OF ORGANIC MATTER

Expulsion rate for major source rocks with generating potential



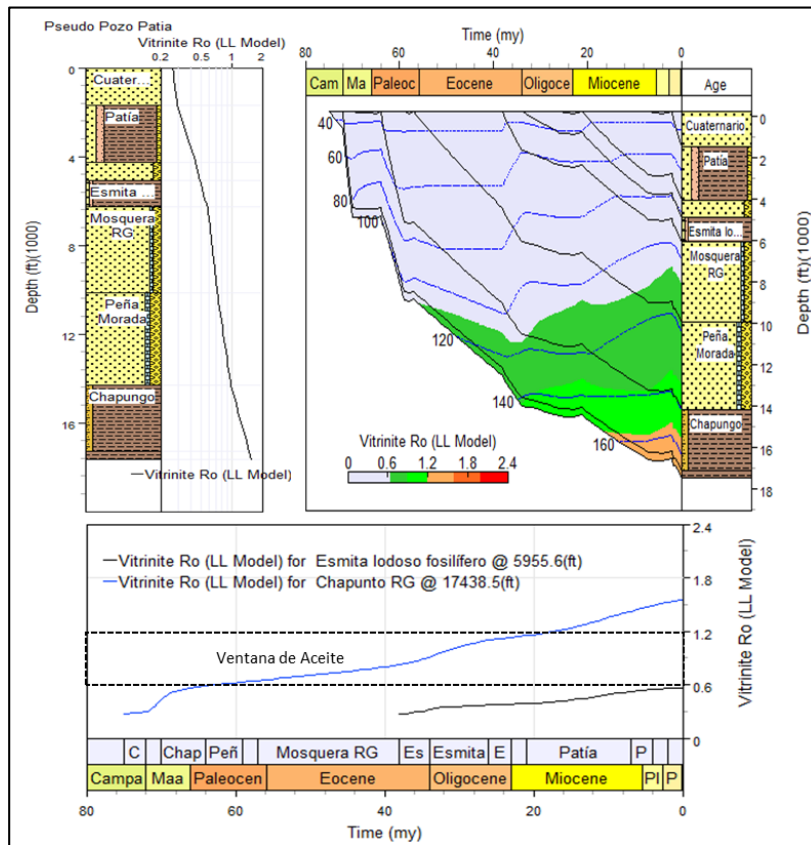
Cuenca	Formación	Ambiente Depósito	Facies Orgánicas	IH	TOC (%)	Espesor (pies)
Cauca Patía	Chimborazo	Llanura Aluvial	Terrestres (Lignito)	150	1.5	50
	Guachinte	Marisma Paludal	Terrestres (Lignito)	150	5.0	50
	Carbonos Guachinte	Marisma Paludal	Carbón Lignito	400	65	10
	Nogales/Chapungo	Marino Plataforma	Marino Siliciclástica	450	3	100



1D MODELING OF PSEUDOPOZOS

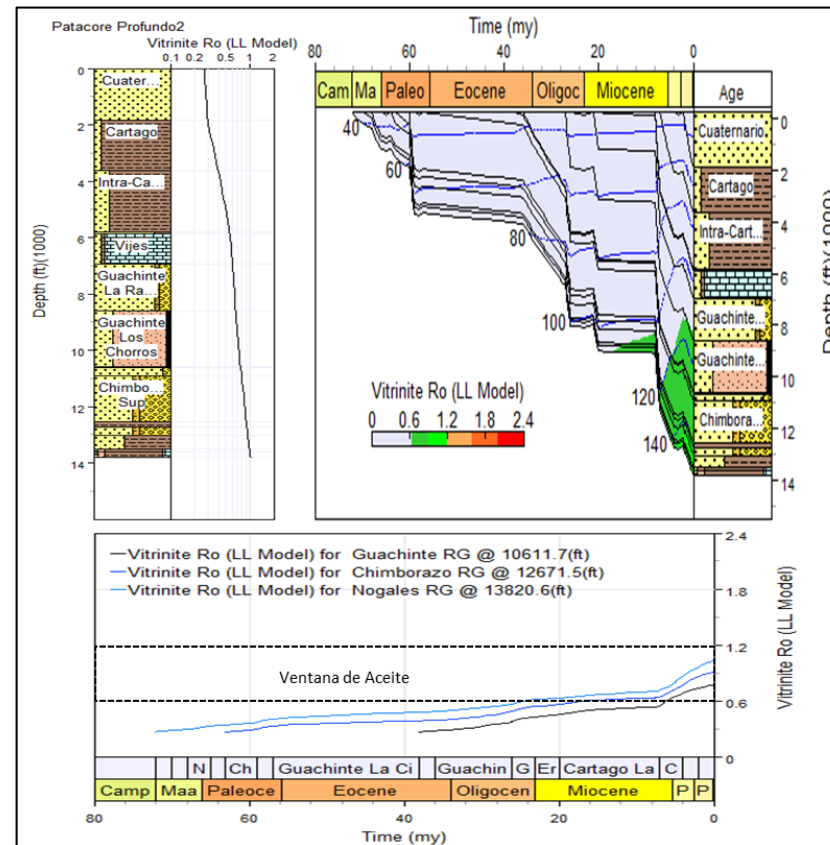
Thermal model based on transient heat flow

Pseudowell Patía-1



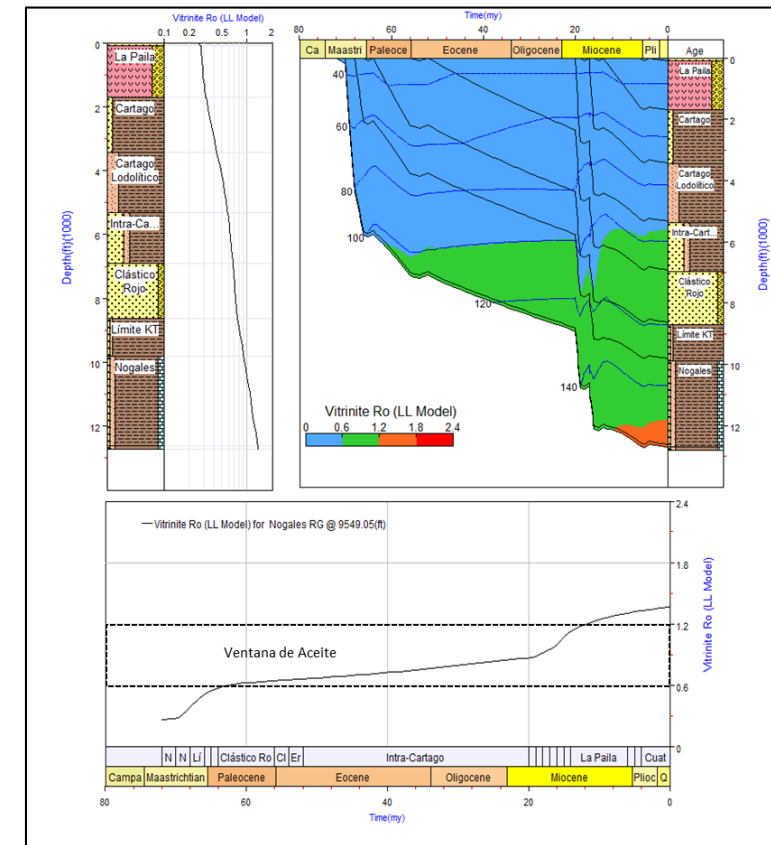
Surface heat flow 53 mW/m²

Pseudowell Patacore Profundo-1



Surface heat flux 53 mW/m²

Pseudowell Cartago-1

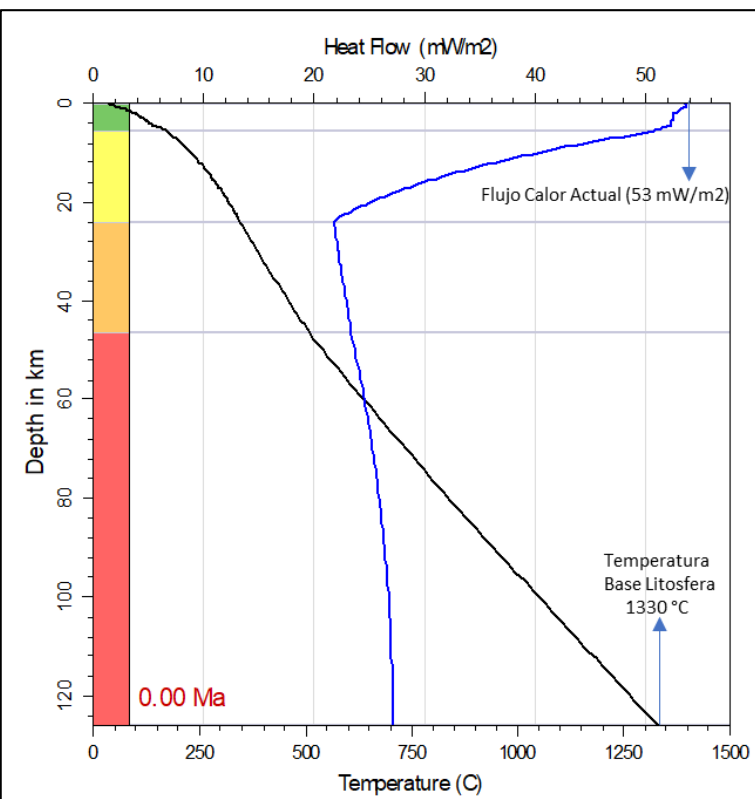


Surface heat flow 57 mW/m²

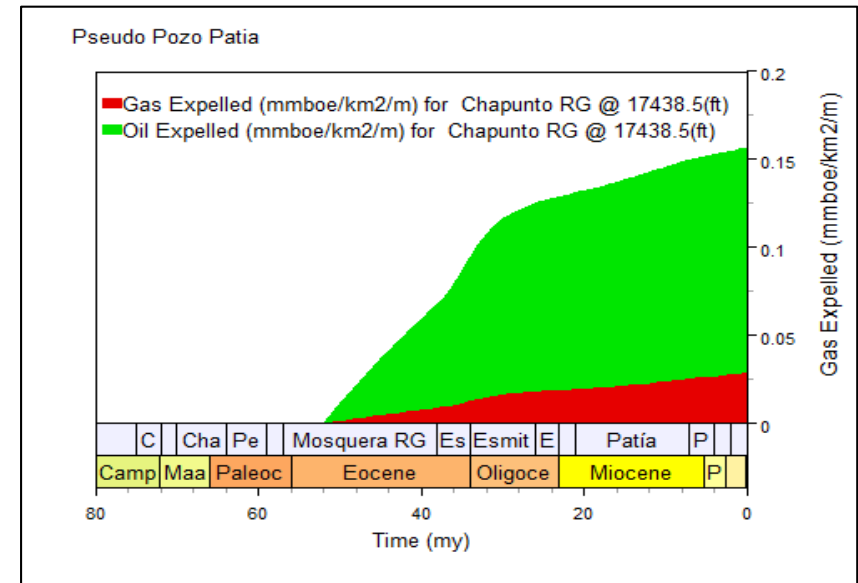
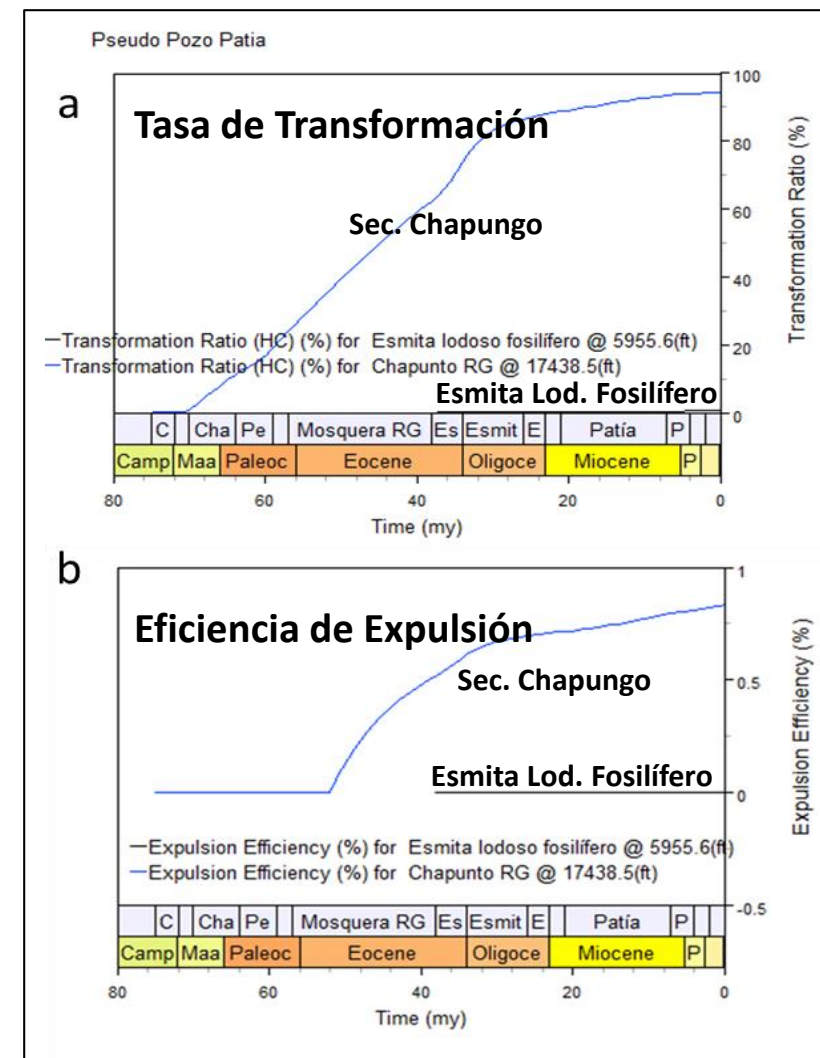
The thermal model assumes a transient heat flow decaying from 1330 °C to the base of the lithosphere to surface temperature

1D MODELING OF PSEUDOPOZOS

Thermal Model and Maturity Pseudopozo Patía 1



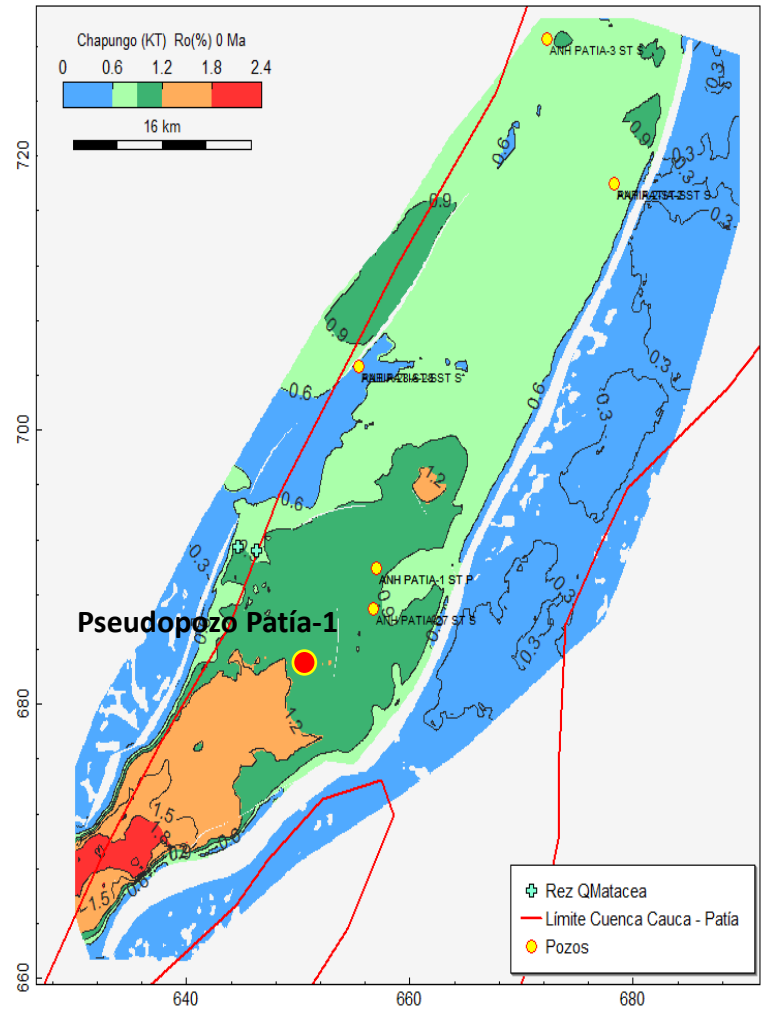
Flujo de calor en superficie 53 mW/m2



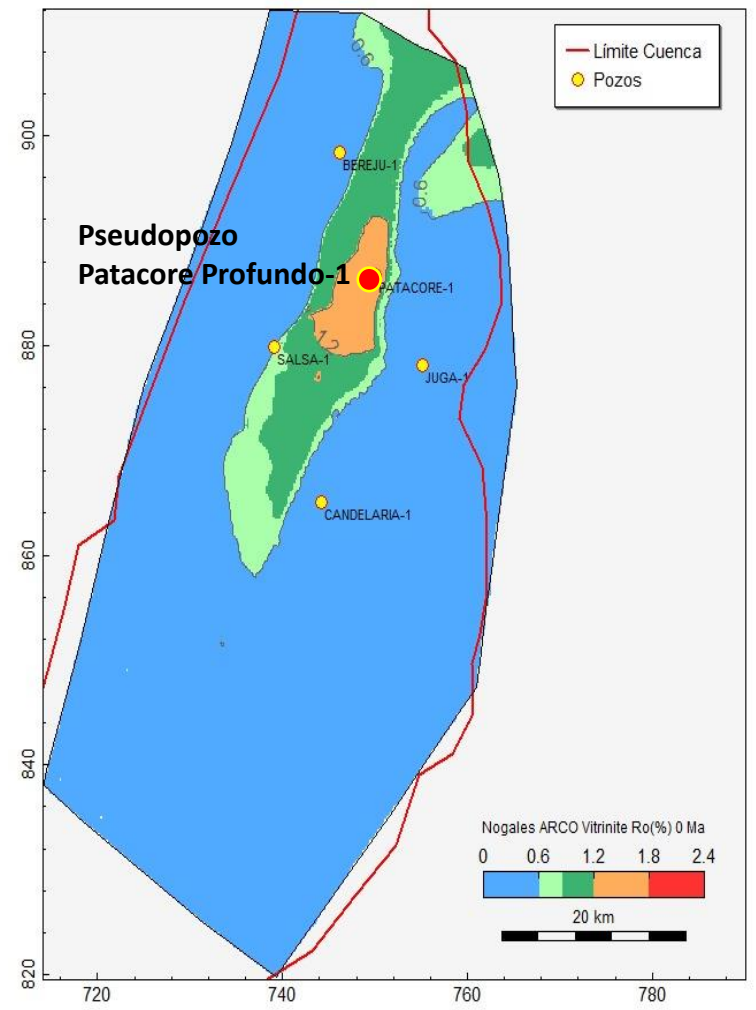
3D MODELING MATURITY AND GENERATION

Vitrinite Reflectance Map – Cretaceous Source Rock

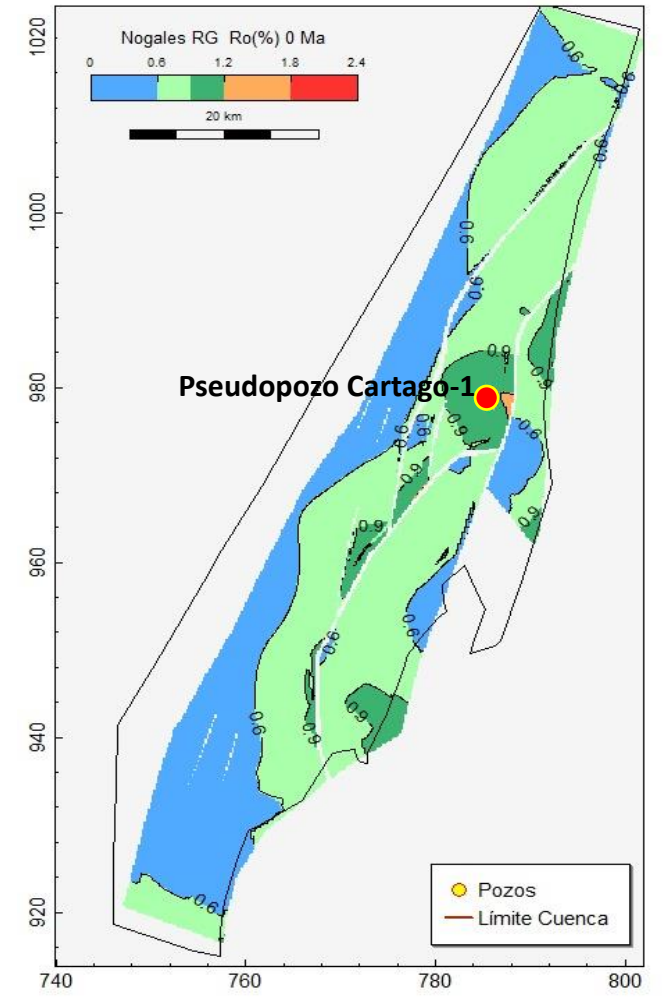
Secuencia Chapungo South Zone



Nogales Formation Central Zone



Nogales Formation North Zone

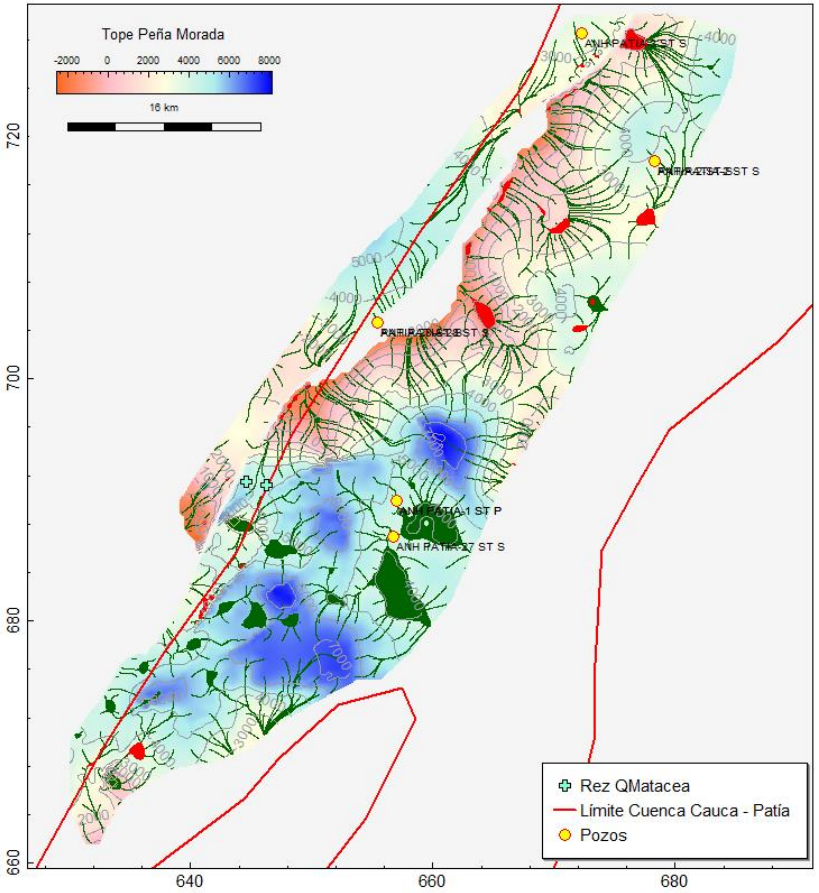


Generation zone - RO > 0.6%

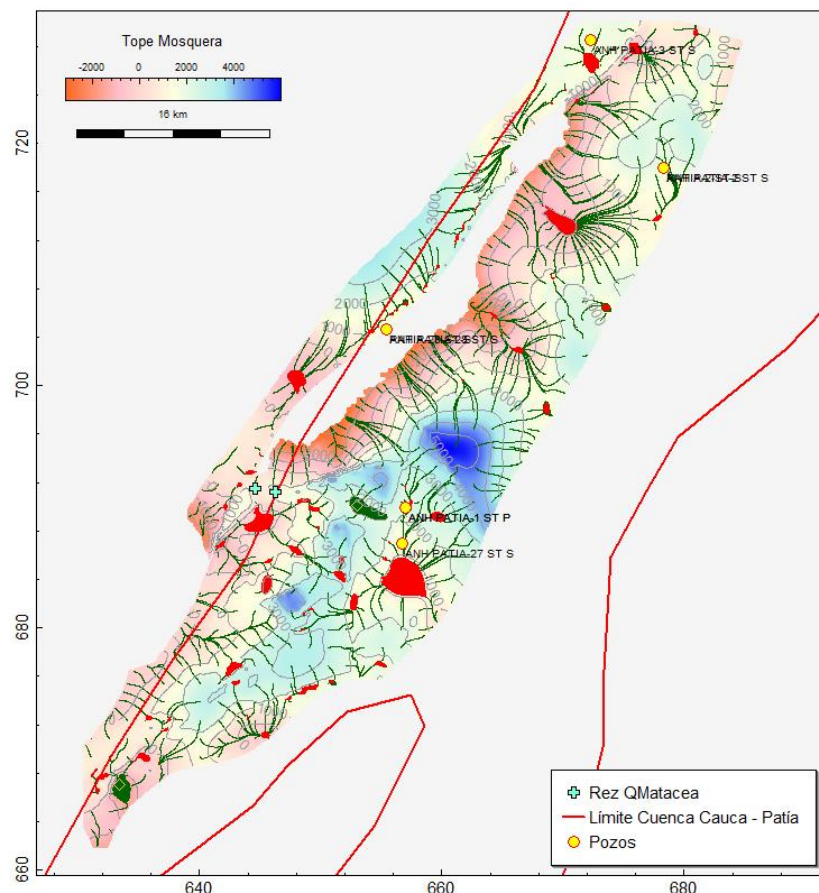
MIGRATION AND CHARGE MODEL

Potential Accumulations in Structural Traps – South Zone

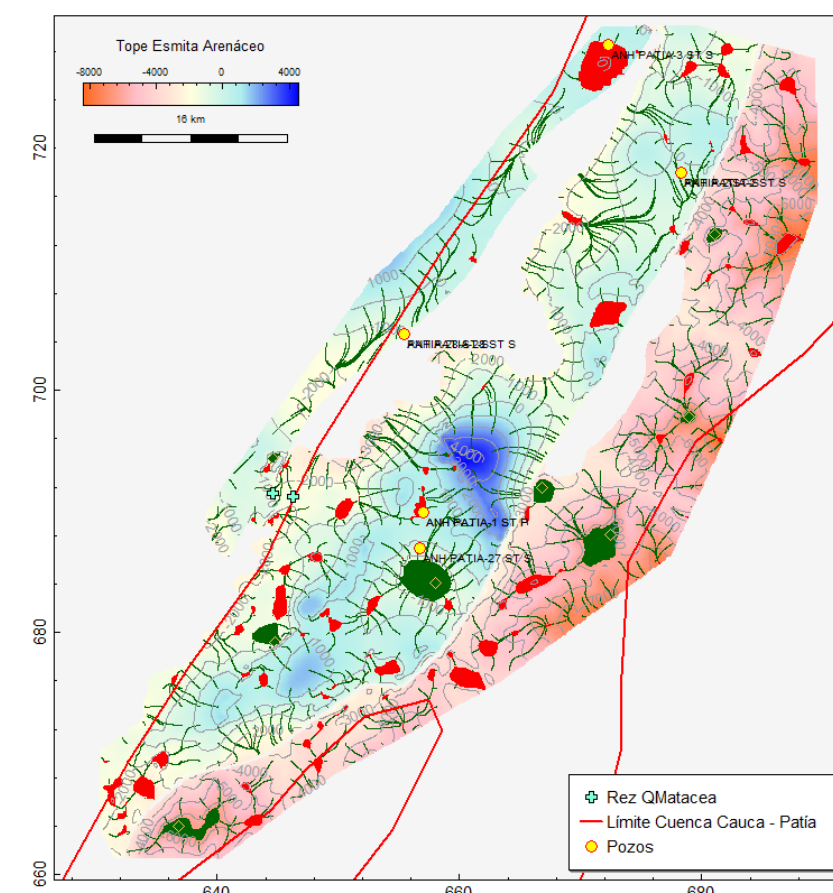
Migration to Top Peña Morada Fm.



Migration to Top Mosquera Fm



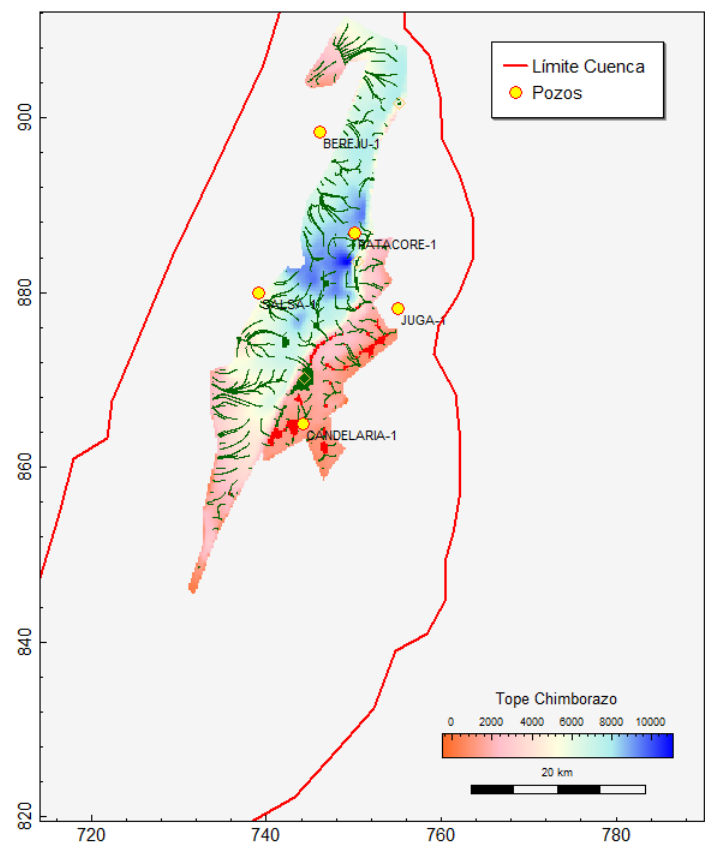
Migration to Top Esmita Arenáceo Fm.



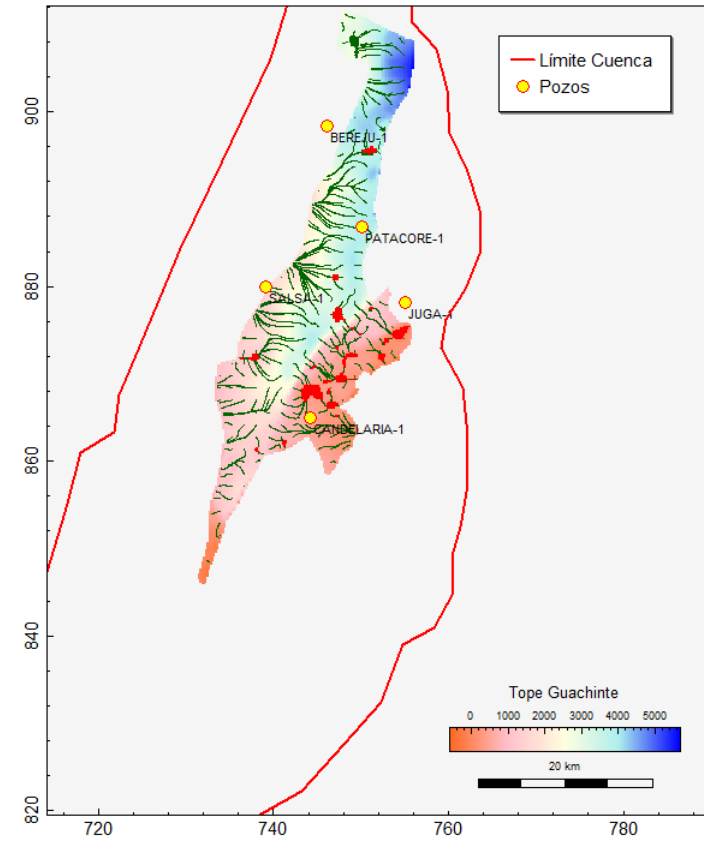
MIGRATION AND CHARGE MODEL

Potential Accumulations in Structural Traps – Central Zone

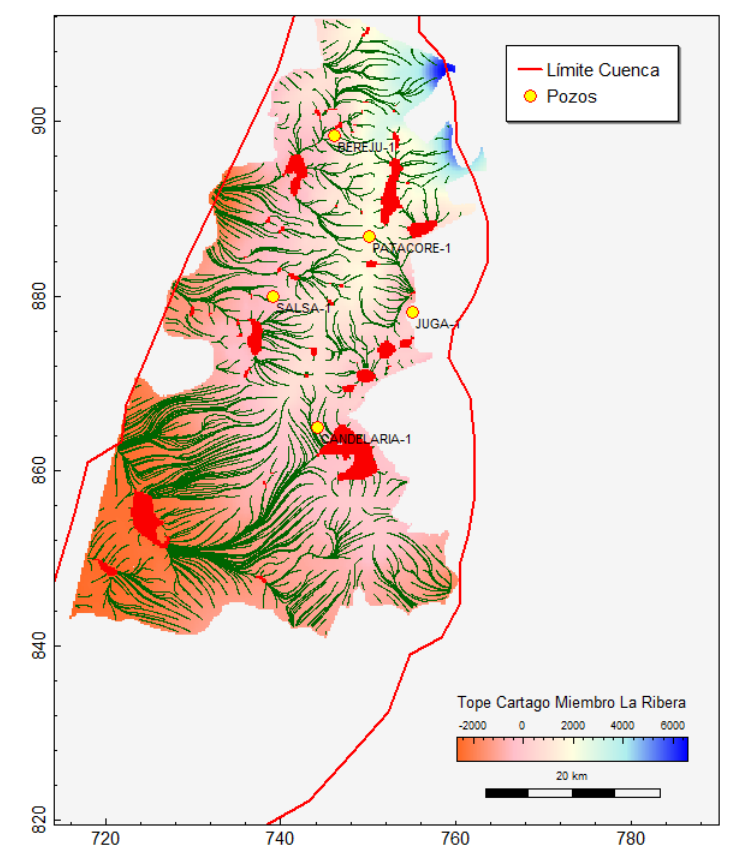
Migration to Top Chimborazo Fm



Migration to Top Fm Guachinte Fm



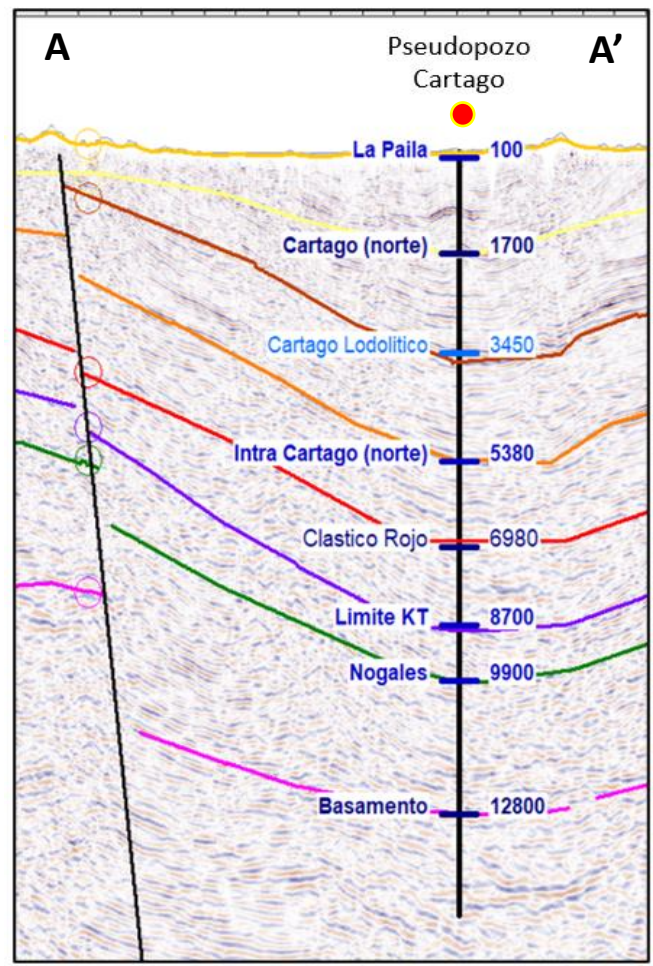
Migration to Top Intra-Cartago Member



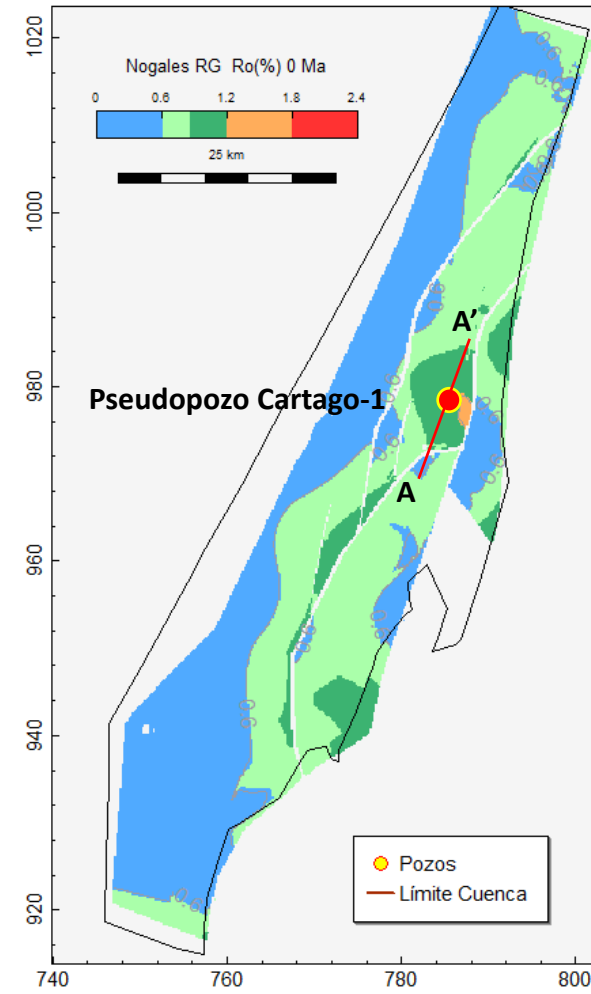
MIGRATION AND CHARGE MODEL

There is no Potential Structural Traps – North Zone

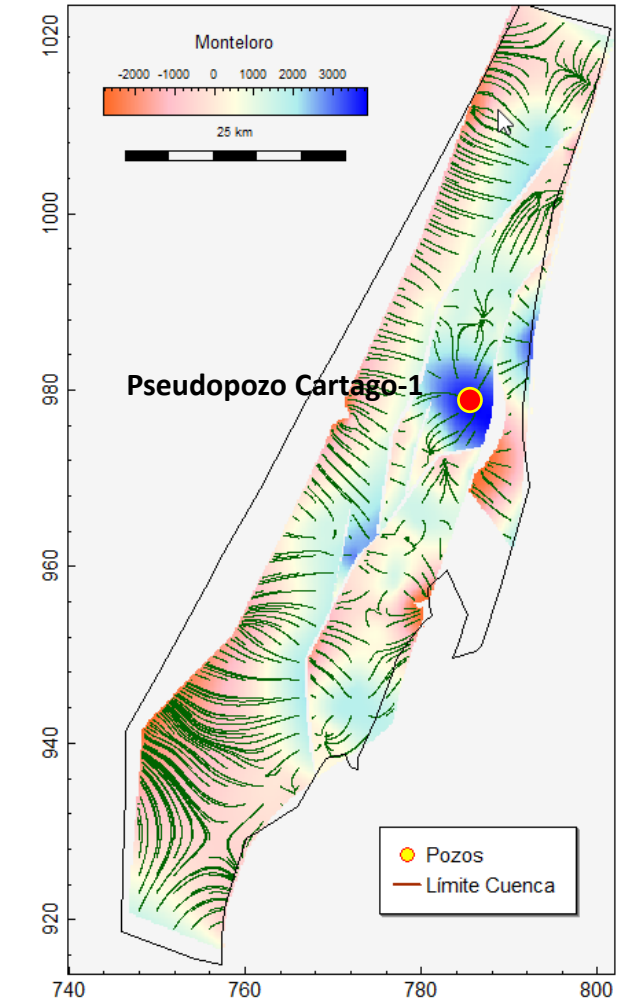
Seismic Section



Nogales Fm. Ro Maturity Map



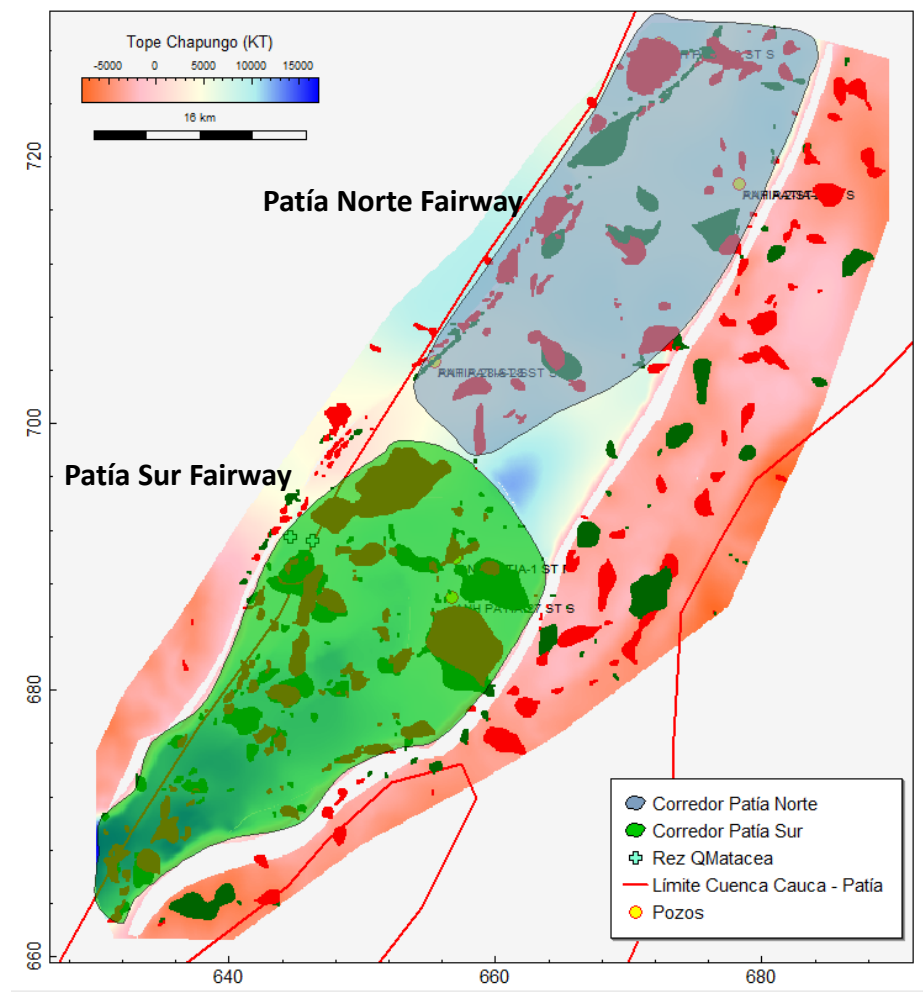
Migration Top of Monteloro Fm



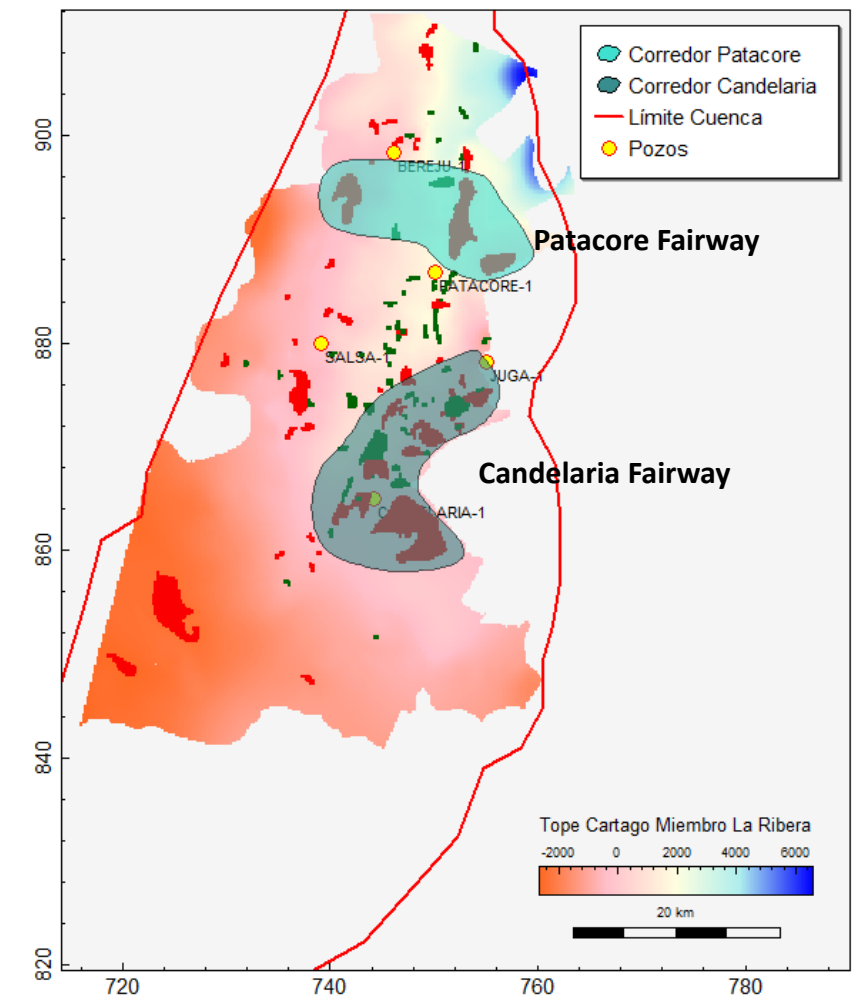
PROSPECTIVE FAIRWAY

Potential accumulations in South and Central Zones

Potential Accumulations South Zone

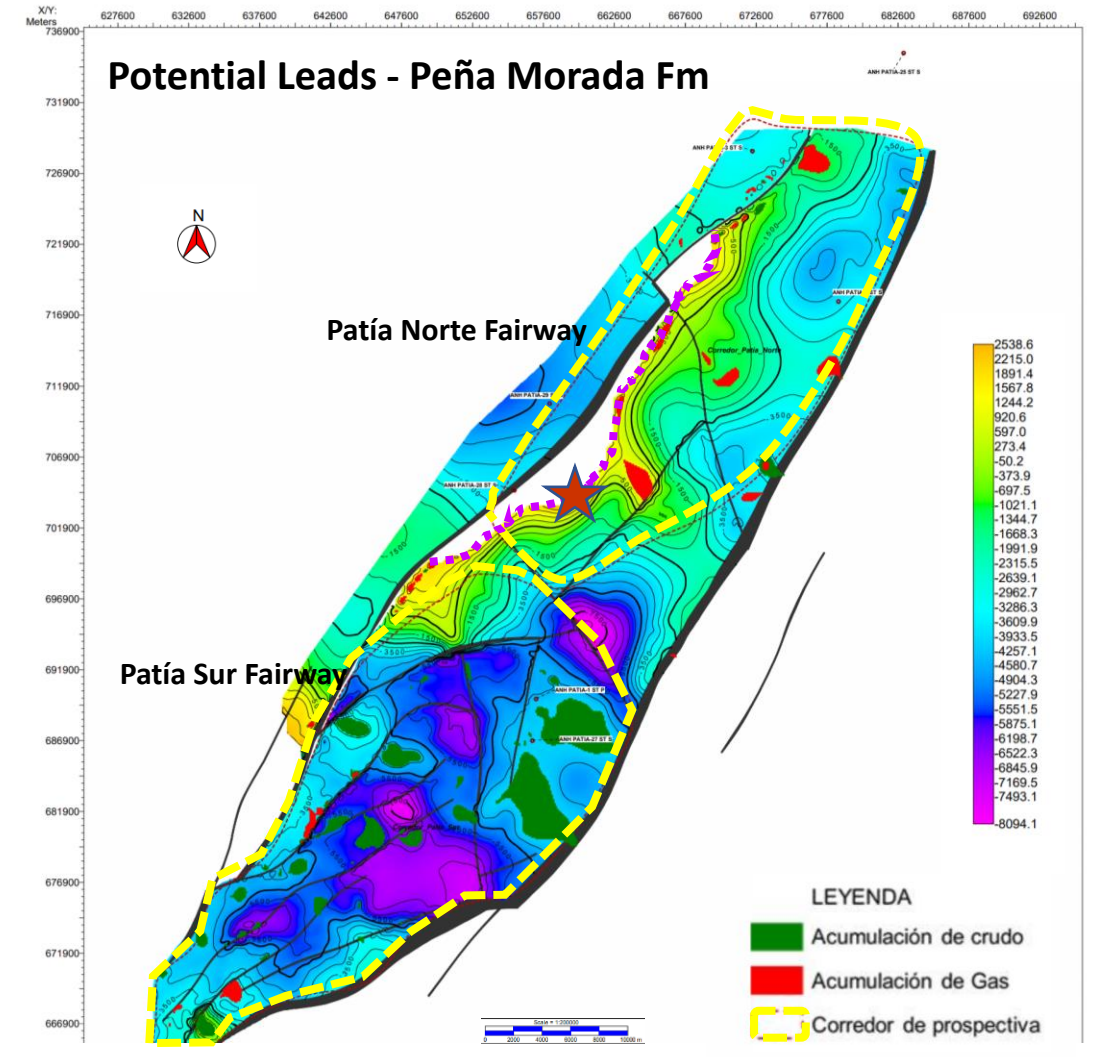
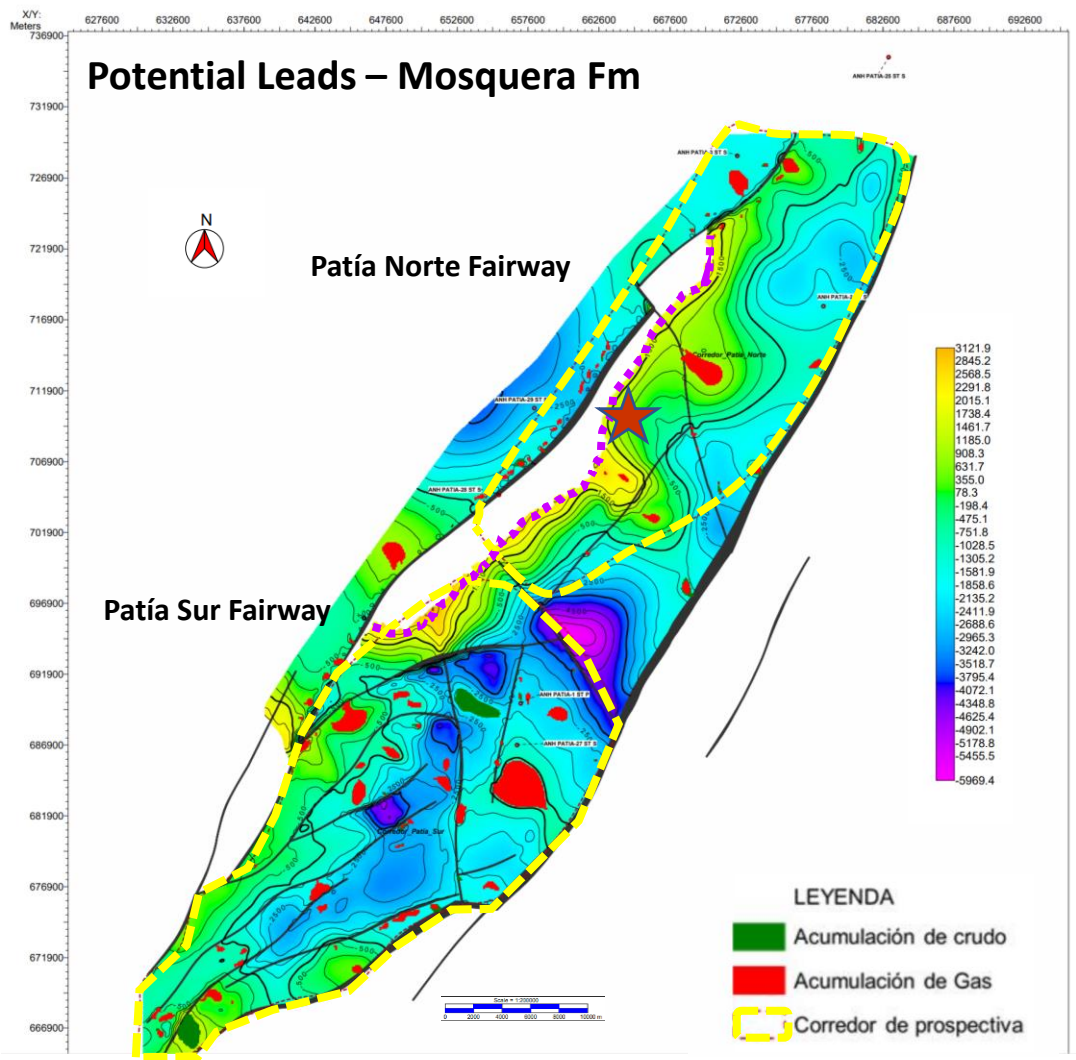


Potential Accumulations Central Zone



PROSPECTIVE FAIRWAY

Potential accumulations in the South Zone



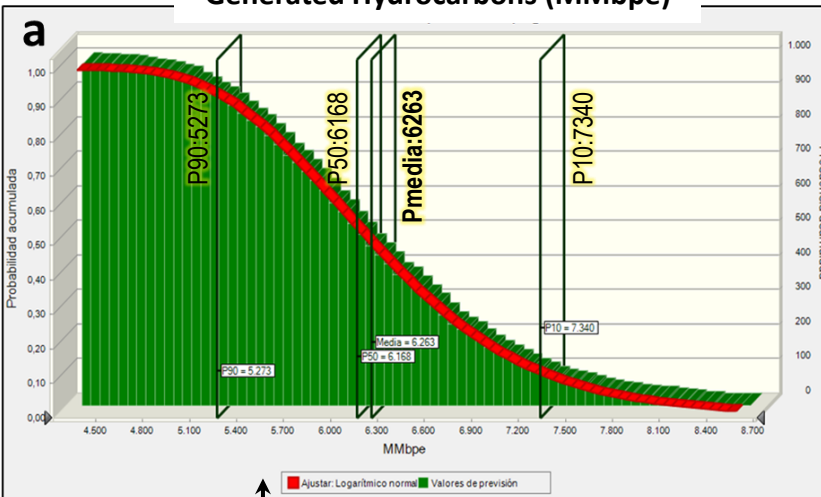
★ Contornos cerrando contra superficies de erosión Potenciales Trampas Estratigráficas

MASS BALANCE AND YET TO FIND EVALUATION

Mass Balance - Probabilistic Calculation of the Cauca Basin- Patía*

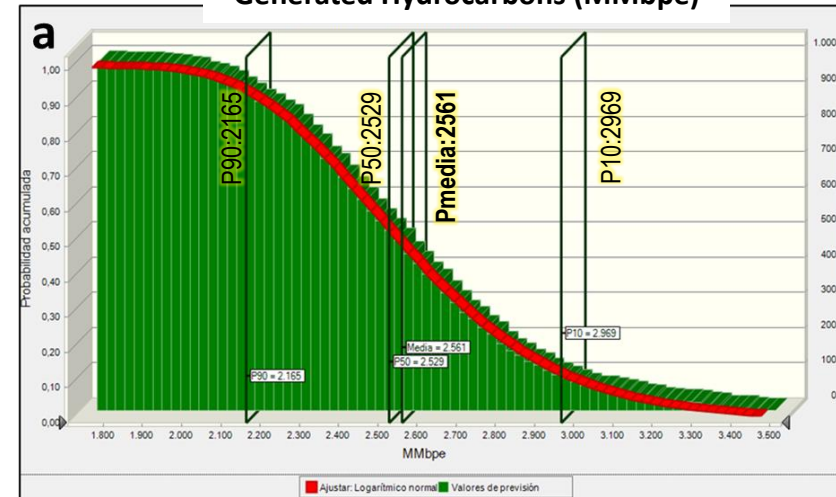
Chapungo Sequence - South Zone

Generated Hydrocarbons (MMbpe)



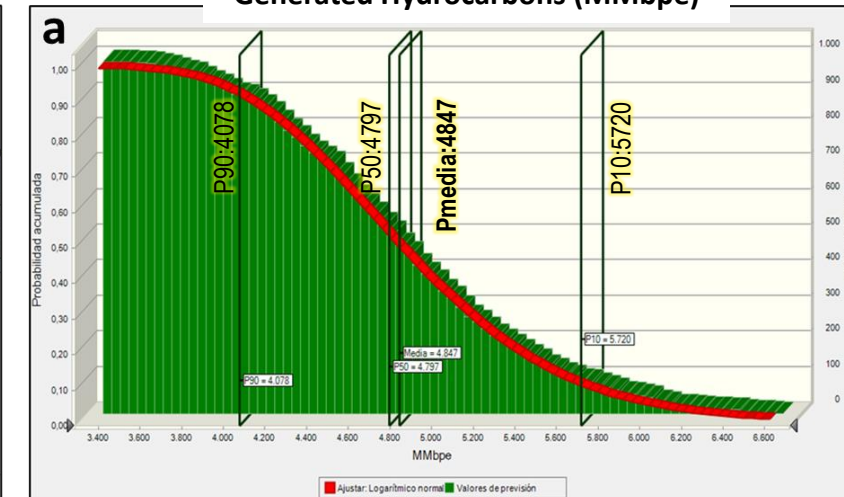
Nogales Fm - Central Zone

Generated Hydrocarbons (MMbpe)



Nogales Fm - North Zone

Generated Hydrocarbons (MMbpe)



PARÁMETROS PARA EL BALANCE DE MASAS DEL ÁREA PATÍA									
SECUENCIA CHAPUNGO									
PARÁMETROS	Unidad	Dist.	P99	P90	P50	P10	P1	Mean	P10/P90
Area Foco Generador	Km2	LogNormal		1.050		1.230		1.139	1
Espesor Roca Generadora Efectiva	Metros	LogNormal		32				34	1
TOC Original	%	Normal		1,60		2,40		2,25	2
Densidad Roca Generadora	g/cm3	Normal		2,35		2,55		2,48	1
Gravedad API	° API	Normal		27,0		33,0		30,00	1
IH Original	mgHC/grTOC	Normal		410,00		480,00		446,48	1
IH Actual	mgHC/grTOC	Normal		45,00		52,00		48,51	1
Factor de Eficiencia de Expulsión	%	Normal		93,00		96,00		94,54	1
HCS. perdidos durante Migración	%	Normal		82,00		87,00		84,54	1
Masa Carbono Orgánico	g TOC	LogNormal	1,70E+15	1,89E+15	2,16E+15	2,51E+15	2,86E+15	2,19E+15	1
Masa Total HCs Generados	Kg HC	LogNormal	6,59E+11	7,36E+11	8,58E+11	1,02E+12	1,23E+12	8,71E+11	1
Hydrocarburos Generados por la Fm. Chapungo	MMbpe	LogNormal	4.734	5.273	6.168	7.340	8.793	6.254	2
Total de Hydrocarburos Disponibles Fm Chapungo	MMbpe	LogNormal	590	709	904	1.128	1.358	914	5

Example Cauca-Patía Sub-basin
Hydrocarbons Generated (MMbpe)

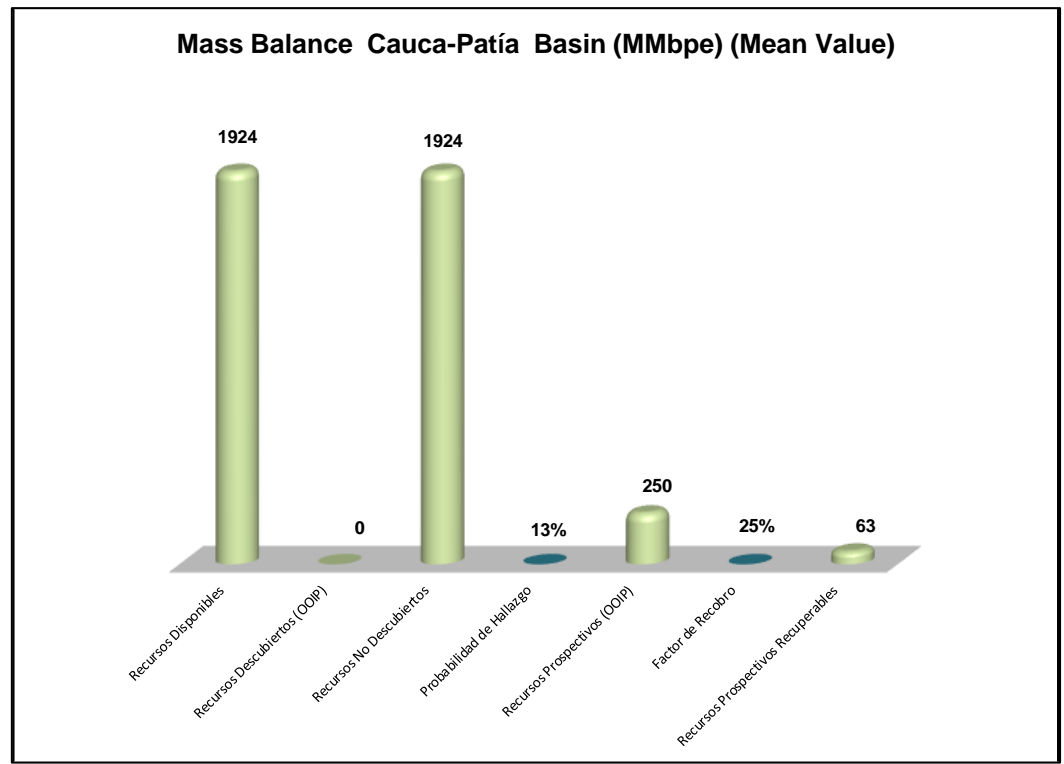
Numbers should be considered only as hypothetical values *

MASS BALANCE AND YET TO FIND EVALUATION

Mass Balance - Probabilistic Calculation of the Cauca Basin- Patía*

PARÁMETROS	UNIDADES	Cauca - Patía			TOTAL
		Patía	Patacore	Cartago	
HC's Generados por la Fm Chapungo	MMbpe	6254	0	0	6254
HC's Disponibles por la Fm Chapungo	MMbpe	914	0	0	914
HC's Generados por la Fm Nogales	MMbpe	0	2553	4852	7406
HC's Disponibles por la Fm Nogales	MMbpe	0	373	637	1010
Total HC's Generados	MMbpe	6254	2553	4852	13660
Recursos Disponibles	MMbpe	914	373	637	1924
Recursos Descubiertos (OOIP)	MMbpe	0	0	0	0
Recursos No Descubiertos	MMbpe	914	373	637	1924
Probabilidad de Hallazgo	%	13%	13%	13%	13%
Recursos Prospectivos (OOIP)	MMbpe	119	49	83	250
Factor de Recobro	%	25%	25%	25%	25%
Recursos Prospectivos Recuperables	MMbpe	30	12	21	63

*FG= Foco Generador



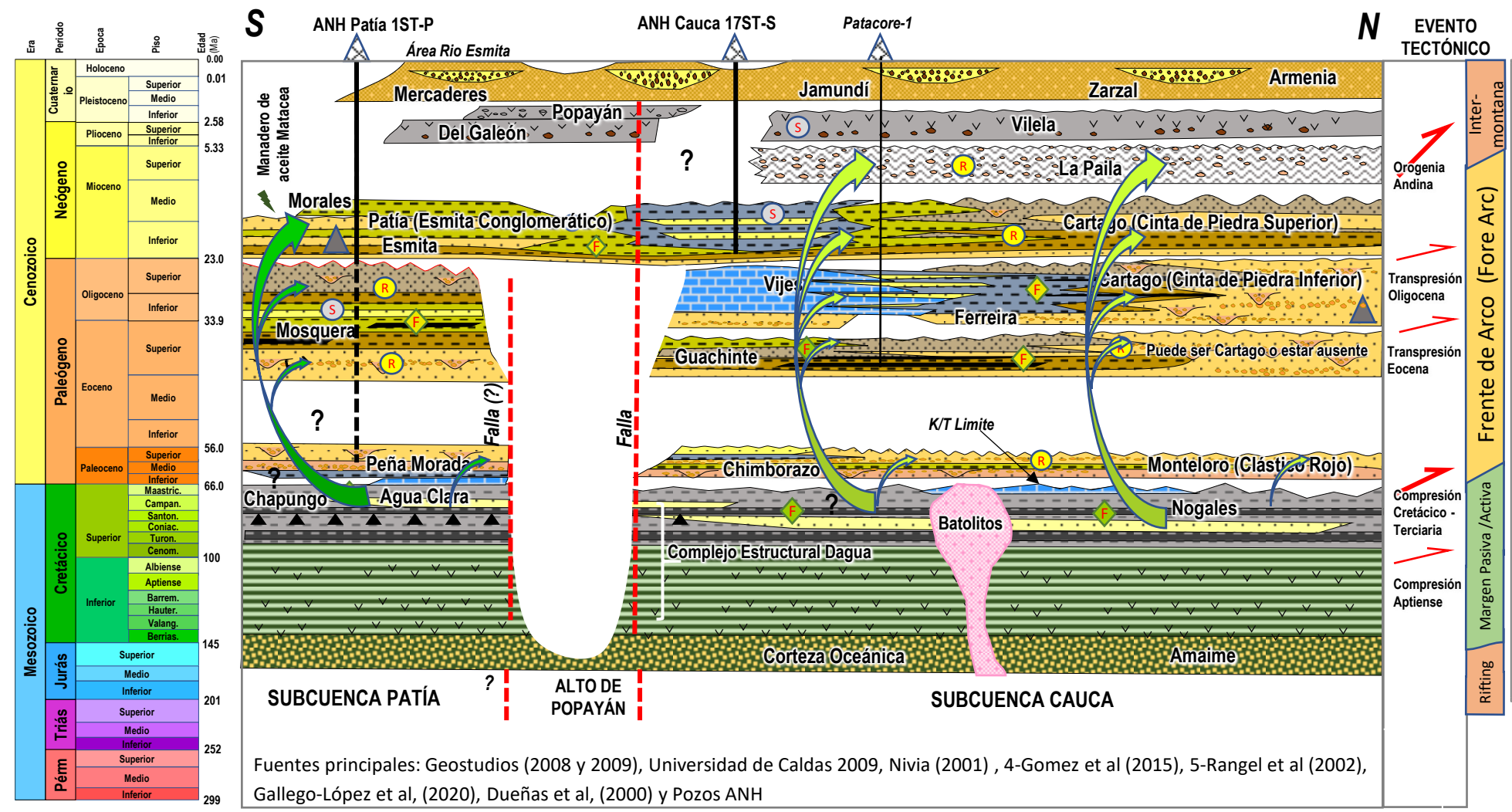
Probable volume of generated hydrocarbons from the Chapungo Sequence and the Nogales Fm. (MEDIA)

- Total generated = **13660 MMbpe** (Probabilistic from the Mass balance model)
- Total available = **1924 MMbpe** (Includes reduction efficiency of expulsion and migration losses)
- Total prospective = **250 MMbpe** (Using a COS of 13%)
- Total prospective recoverable = **63 MMbpe** (Considering 25% of recovery factor)

Numbers should be considered only as hypothetical values *

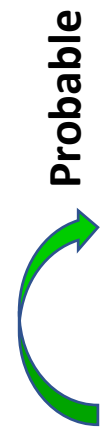
CHRONOSTRATIGRAPHY - CAUCA-PATÍA BASIN

Cauca-Patía Petroleum Systems



Fuentes principales: Geostudios (2008 y 2009), Universidad de Caldas 2009, Nivia (2001), 4-Gomez et al (2015), 5-Rangel et al (2002), Gallego-López et al, (2020), Dueñas et al, (2000) y Pozos ANH

Petroleum Systems





SUMMARY

- ❖ The Cauca-Patía basin contains all the geological elements to make it attractive to hydrocarbon exploration
- ❖ There are active oil seeps and rocks with hydrocarbon generation potential in the Late Cretaceous and Tertiary section
- ❖ The rocks with the greatest generating potential in the Cretaceous are the Nogales Formation and the Chapungo Sequence (HI=450 and TOC=3%) and in the Tertiary the coals of the Guachinte Formation (HI=400 and TOC=65%) and the mudstones of the Chimborazo and Guachinte Formations (HI=150 and TOC=1.5%)
- ❖ The best rocks with reservoir potential are the sandstones and conglomerates of the Chimborazo, Guachinte and Mosquera Formations (Paleogene) with average porosity 9.4 to 10.9% and permeabilities of 3.1 to 24.2 mD, and the Paila and Patía Formations (Neogene) with average porosity 13.8 to 25.1% and permeabilities of 14.5 to 1670 mD
- ❖ There are rocks with sealing potential scattered throughout the Tertiary section especially the mudstones of the Esmita and Cartage Formations



SUMMARY

- ❖ The structural configuration of the basin is predominantly transpressive and is the result of multiple tectonic events associated with a passive margin changing to active during the Cretaceous, fore arc in the Paleogene and intermontane in the Late Miocene
- ❖
- ❖ Sedimentation during the fore-arc phase of the basin maintained a predominance of continental environments proximal to the east and distal intertidal to shallow-marine to the west, and dominance in the provenance of sediments from the Central Cordillera. The intercalation of these environments favors the presence of sandy levels, potentially reservoirs, interbedded with fine-grained units which have sealing rock character
- ❖ The analyses presented here are based on abundant surface geological information and limited well information which is represented by the Patacore-1 and ANH Patía-1ST-P wells, (deficient in chronostratigraphic information), 13 shallow wells, gravity data and spaced 2D seismic information from poor and medium to good resolution
- ❖ In general, the interpretation of the deep surfaces presented here is conceptual, delineated by integrating thicknesses of outcrop stratigraphic sections, geological mapping, satellite imagery and gravity data



SUMMARY

- ❖ The Patacore-1 well has incomplete information that seems to indicate the presence of hydrocarbons in the area; however, no final well reports from the operating company that could verify these indications have not been found yet.
- ❖ Poor quality of some electrical well records was observed due to the absence of registered sections, apparent deficiency in quality control and lack of core GR. These deficiencies, as well as the absence of fluid measurements in wells, such as water salinity, limit the effectiveness of electrical log analyses and the reliability of their hydrocarbon calculations
- ❖ The seismic information is concentrated in three areas that in this work were called North Zone, Central Zone and South Zone and thus the generated maps were identified. The quality is medium to good in the central area but, in the south and north, its quality does not allow the generation of a reliable map.
- ❖



SUMMARY

- ❖ Statistical analyses of mass balance estimate resources generated of 6254 MMboe for the Patía Sub-basin, 2553 MMboe in the southern part of the Cauca sub-basin and 4852 mmboe for the northern part of the Cauca sub-basin
- ❖ The resource values generated should be considered hypothetical as there is not enough geological control to generate a more rigorous volumetric assessment across the basin
- ❖ The highest exploratory risk in the basin is related to the current impossibility to determine the presence, quality, extent and maturity level of the generating rock, especially of the Cretaceous units
- ❖ Another great exploratory risk is concentrated in the inability to make a reliable mapping of the units of interest to determine depth, structural architecture and delineation of traps as well as to make models of burial, maturity and generation of organic matter



RECOMMENDATIONS

- ❖ It is necessary to standardize as practically as possible the stratigraphic nomenclature in the basin and to clearly define the equivalences between the contemporary units
- ❖ Organize a database for each sedimentary basin that includes all existing surface and underground information relevant to hydrocarbon exploration
- ❖ Advance a detailed program of evaluation of ditch cutting samples from exploratory wells to determine age, reservoir parameters, sealing rocks, potential source rocks and presence of hydrocarbon
- ❖ Make a detailed stratigraphic survey of the Upper Cretaceous units along the edges of the basin to determine, at the regional level, their potential as source rock
- ❖ Design seismic acquisition programs looking for an optimal location in relation to the structural geology of the basin and with appropriate evaluation of the energy sources to obtain interpretable information of the underground units



RECOMMENDATIONS

- ❖ Reprocessing the existing seismic information adjusting to the acquisition energy (vibro vs dynamite) seeking to improve the image not only in deep areas but also in shallow areas where there is presence of good reservoirs and potential traps
- ❖ Drill stratigraphic control wells with a rigorous data collection plan that includes sampling rock, fluids, electrical and seismic records under the supervision of a qualified well-site geologist.
- ❖ Promote exploration with private companies to advance programs that help to mitigate the risk and concentrate investment in areas of greater exploration potential within each sub-basin



Thank you