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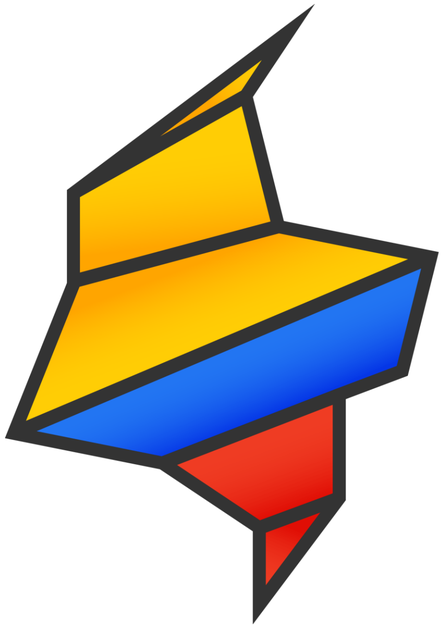
El futuro es de todos

Minenergía



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EAGE

GEOLOGICAL INTEGRATION, EVALUATION OF OIL SYSTEMS AND PROSPECTIVITY OF THE TUMACO – SAN JUAN FOREARC BASINS, NORTHWESTERN SOUTH AMERICA

By
Universidad Nacional de Colombia

april 30th, 2021

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CONTENT

1. Geological setting

By Orlando Hernández, Ms, PhD

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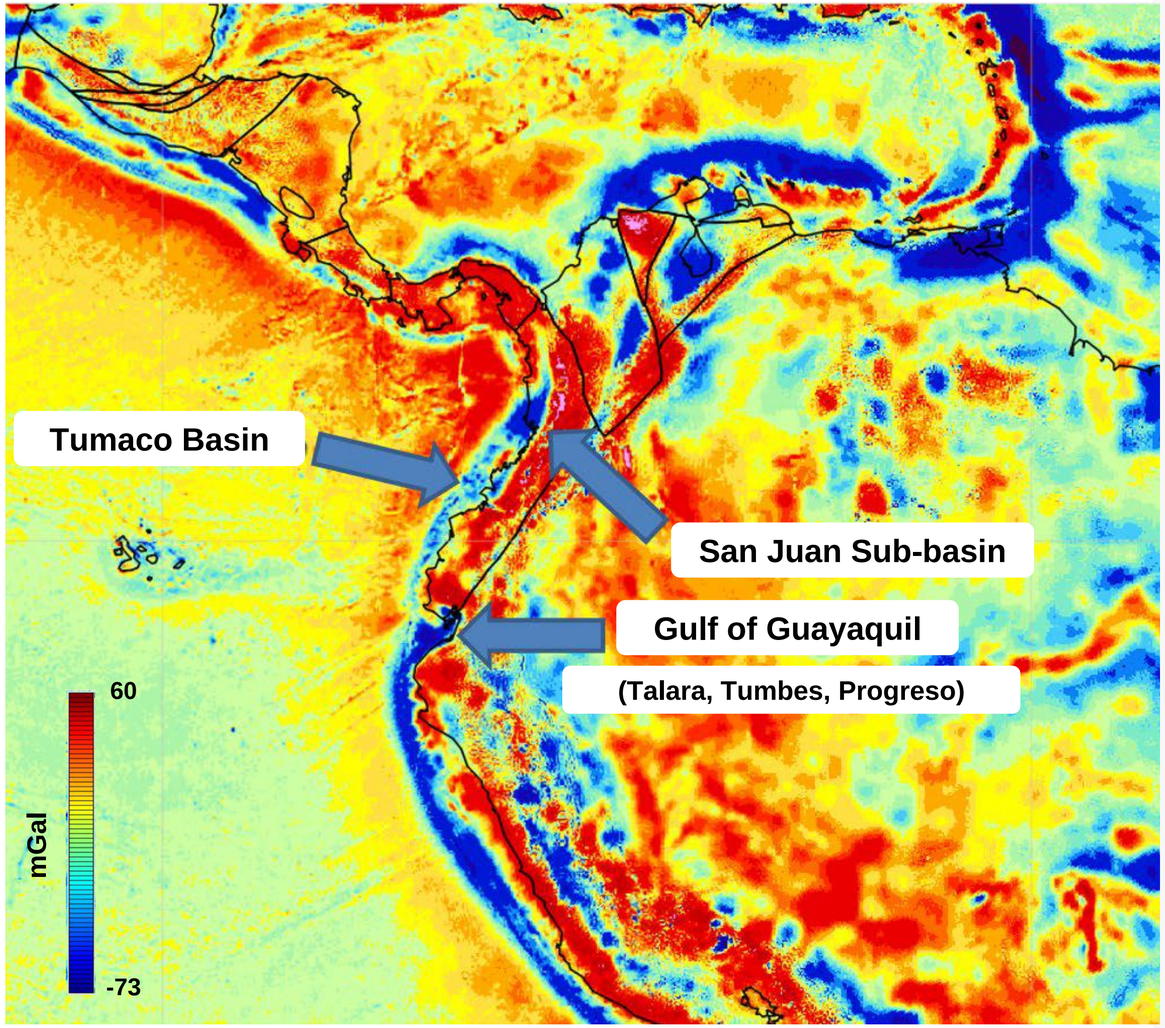
GEOLOGICAL SETTING



(modified from Bonvalot et al., 2012)

Potential in subduction zones

The hydrocarbon fields of commercial relevance in subduction zones are reduced to a few, for example, in the American continent, in the Cook Inlet and Sacramento basins (USA) and the Talara basins (Peru) and Progreso (Ecuador).

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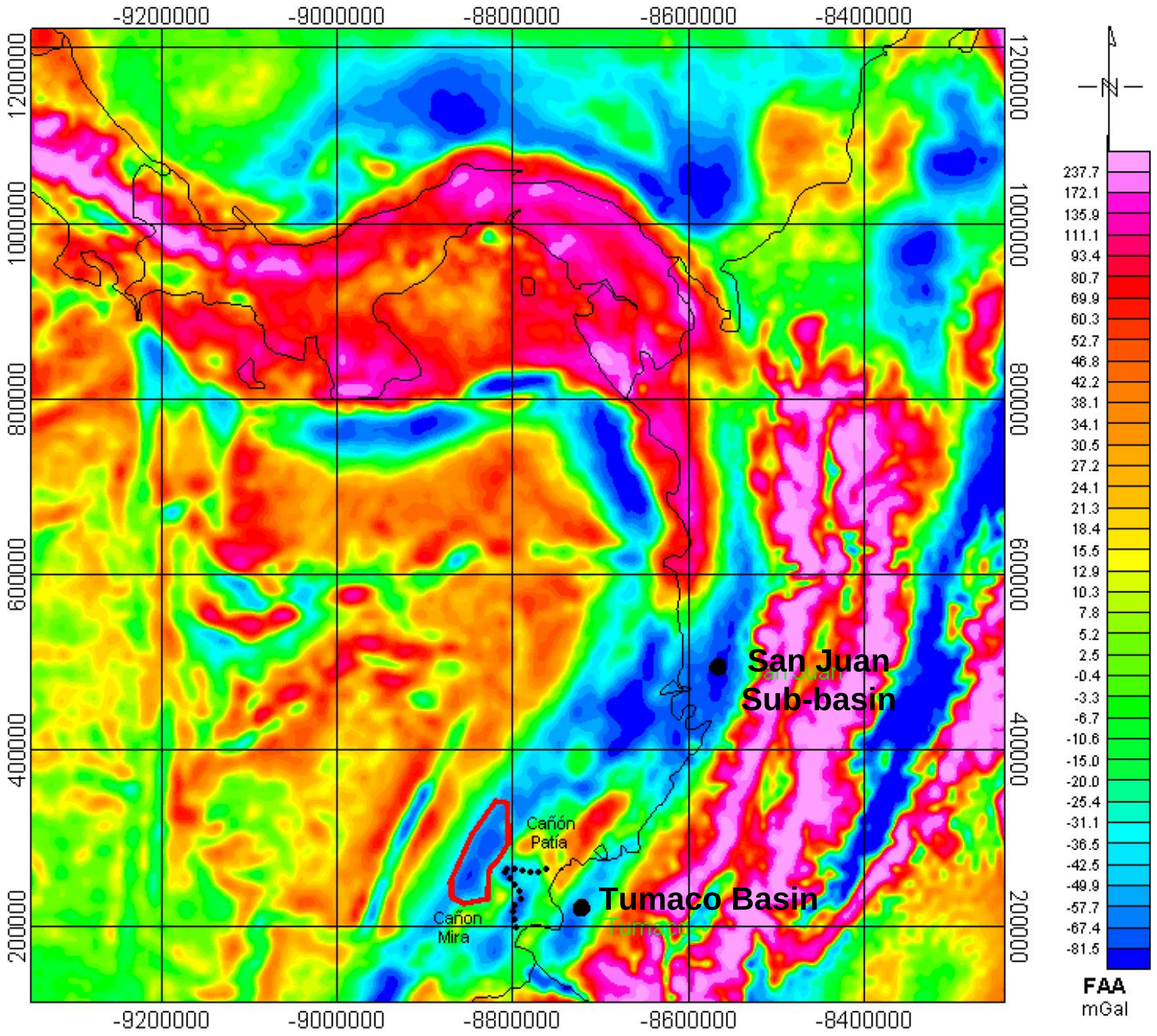
POTENTIAL FIELD MODELS



Free air Anomaly map

Gravity anomalies

Negative gravity anomalies outline the Tumaco and San Juan basins, while positive gravity anomalies coincide with the Remolino Grande high in Tumaco and the western limit of the San Juan sub-basin, formed by the Itsmina high and the Serrania del Baudo.

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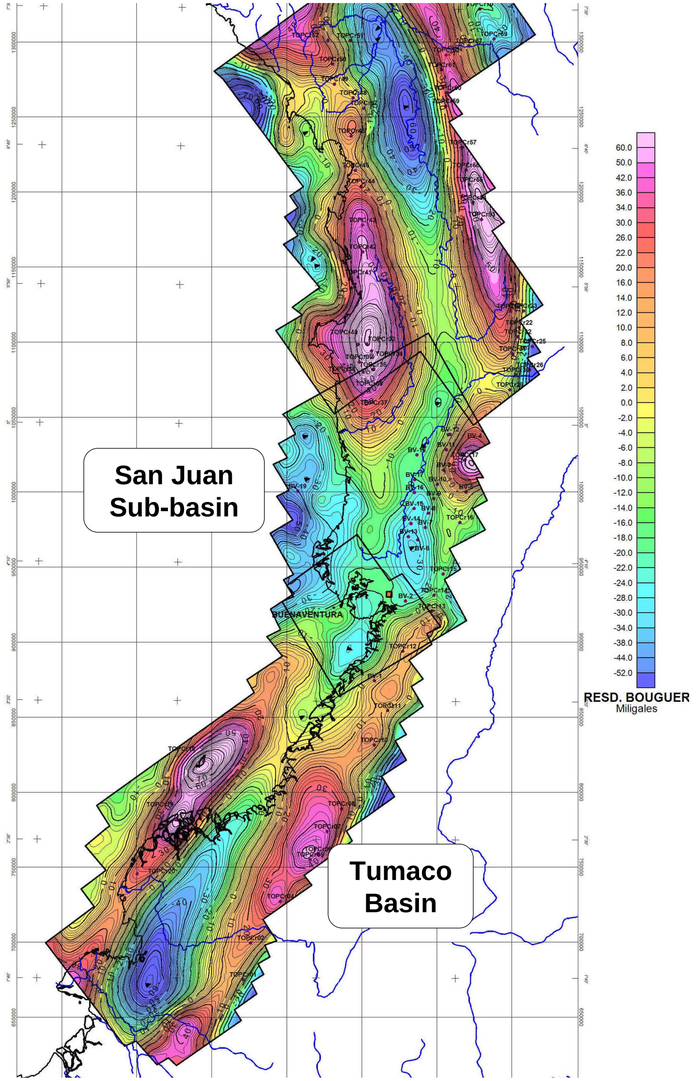
GEOLOGICAL SETTING



(Carson, 2006)

Sedimentary basins

The most negative gravity anomalies (<-64mGal) are useful to outline the Chocó (north) and Tumaco (south) Basins.

The variation of the negative gravity anomalies reflects changes in geometric and thickness of the sedimentary basin

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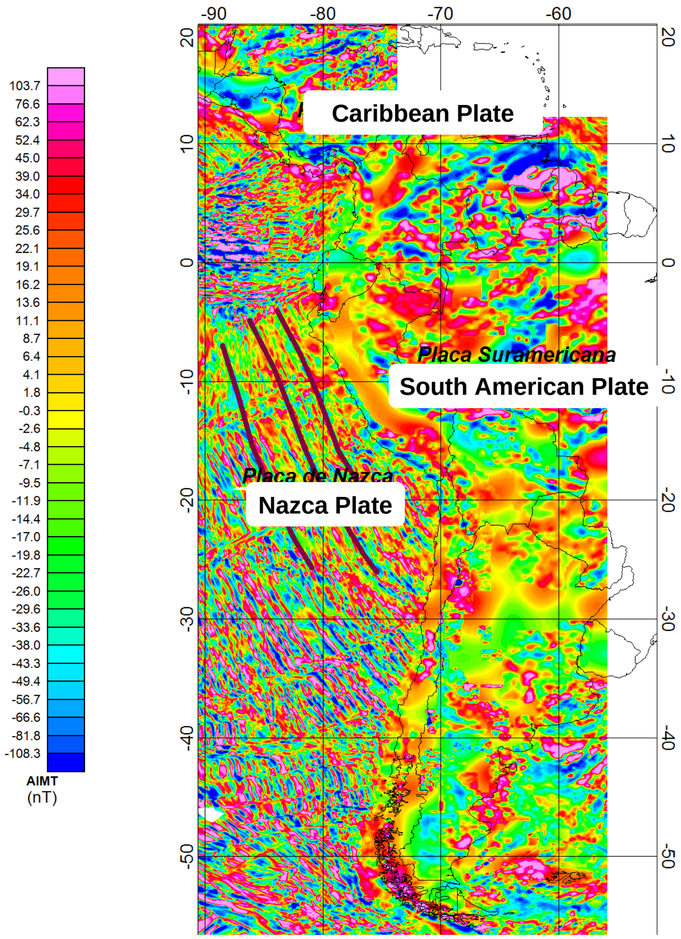
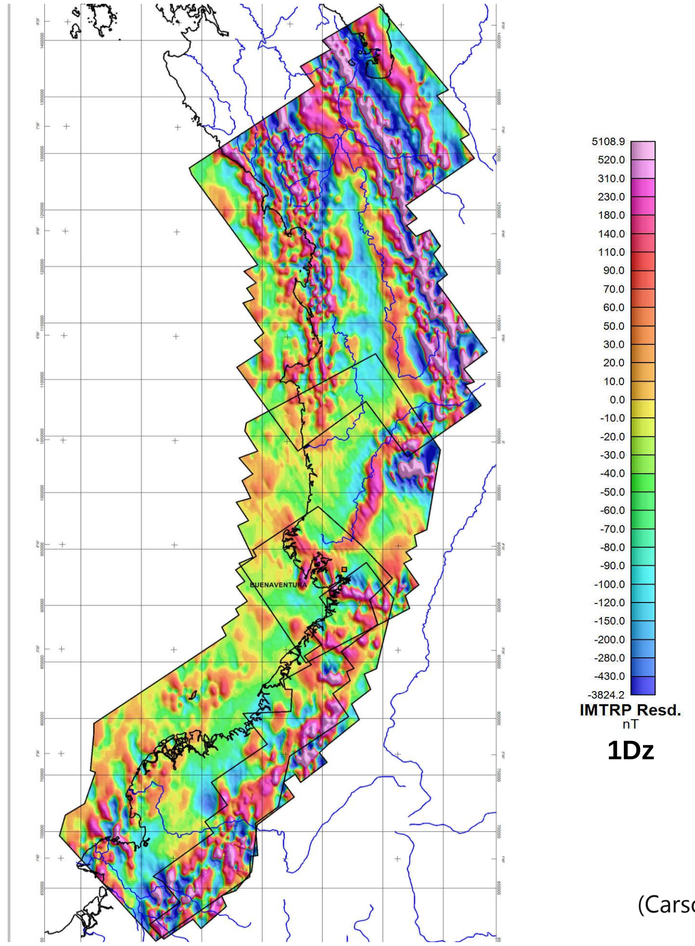
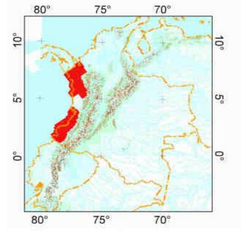
POTENTIAL FIELD MODELS

Total field magnetic anomaly (TFMA)



First vertical derivative of TFMA





Location

(Carson, 2006)

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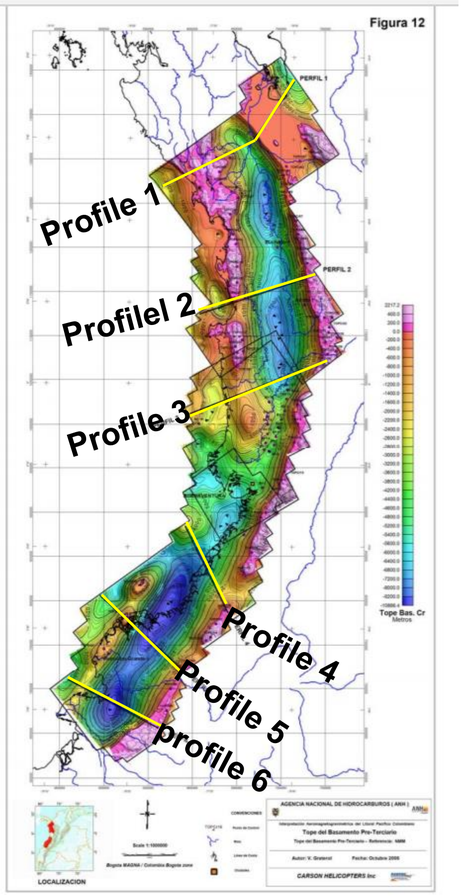
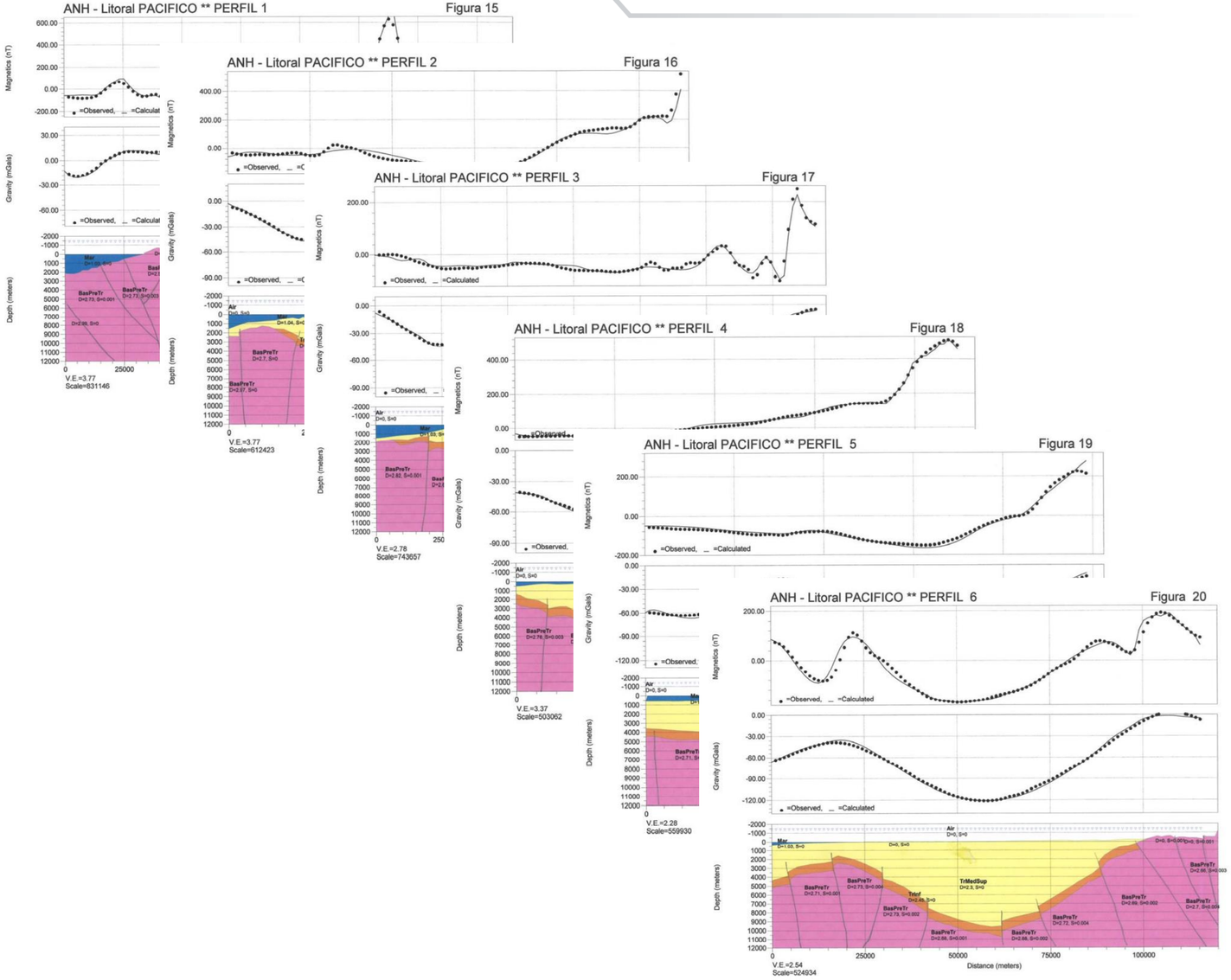
POTENTIAL FIELD MODELS





Fuente:

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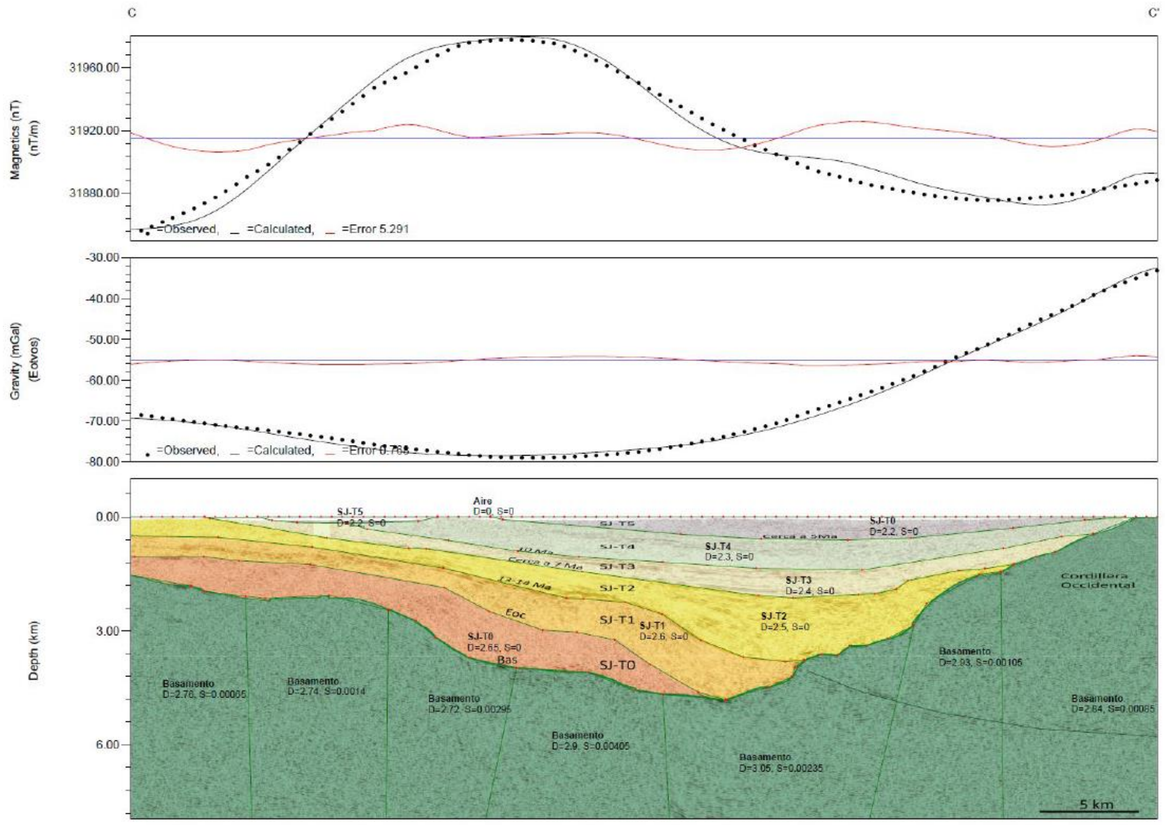
POTENTIAL FIELD MODELS



Profile of potential methods along a seismic transect in the San Juan sub-basin

2D gravity and magnetic modeling

The geometry and thickness of the sedimentary basins were obtained By 2D gravity and magnetic modeling

These models help to integrated seismic data interpretation and borehole data.

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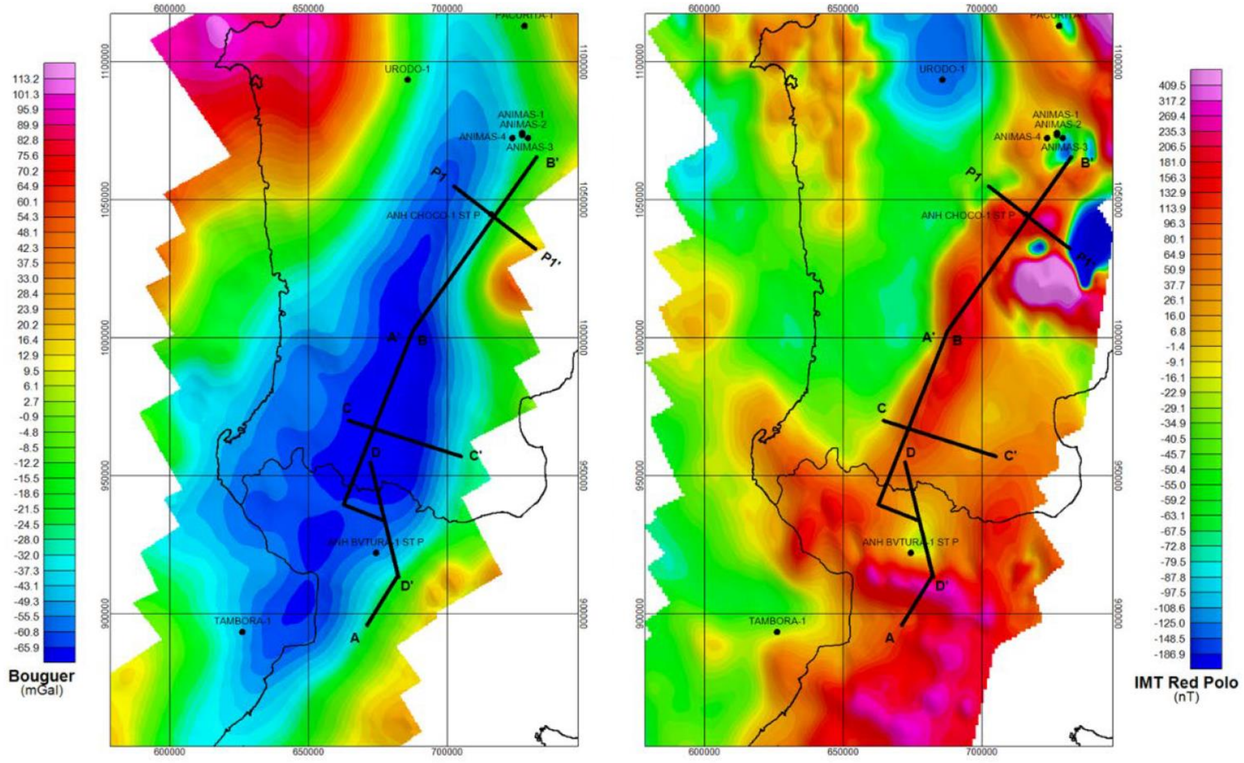
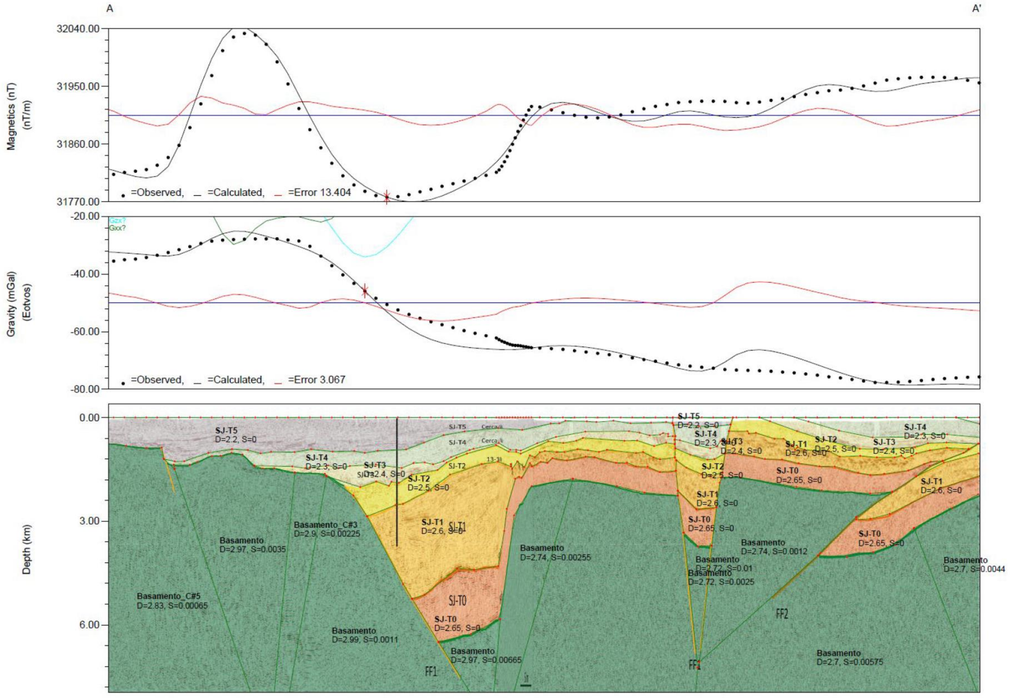
POTENTIAL FIELD MODELS

Gravity and magnetic data integration



Bouguer Anomaly

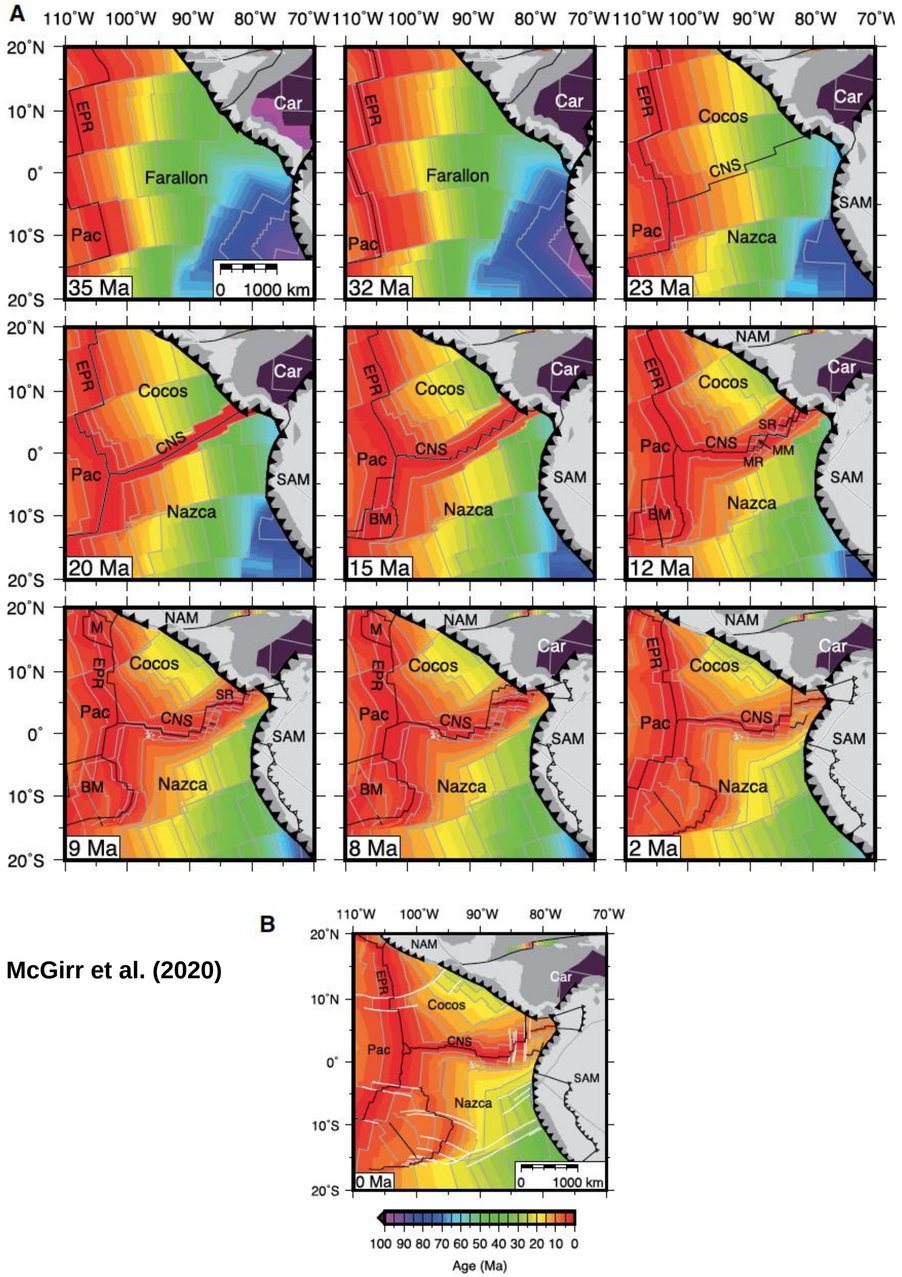
Total magnetic intensity (TMI) reduced to the pole



Gravity and magnetic modeling of the seismic transect D-D '

2. Stratigraphy and Paleogeography

By Germán Bayona, Ms, PhD

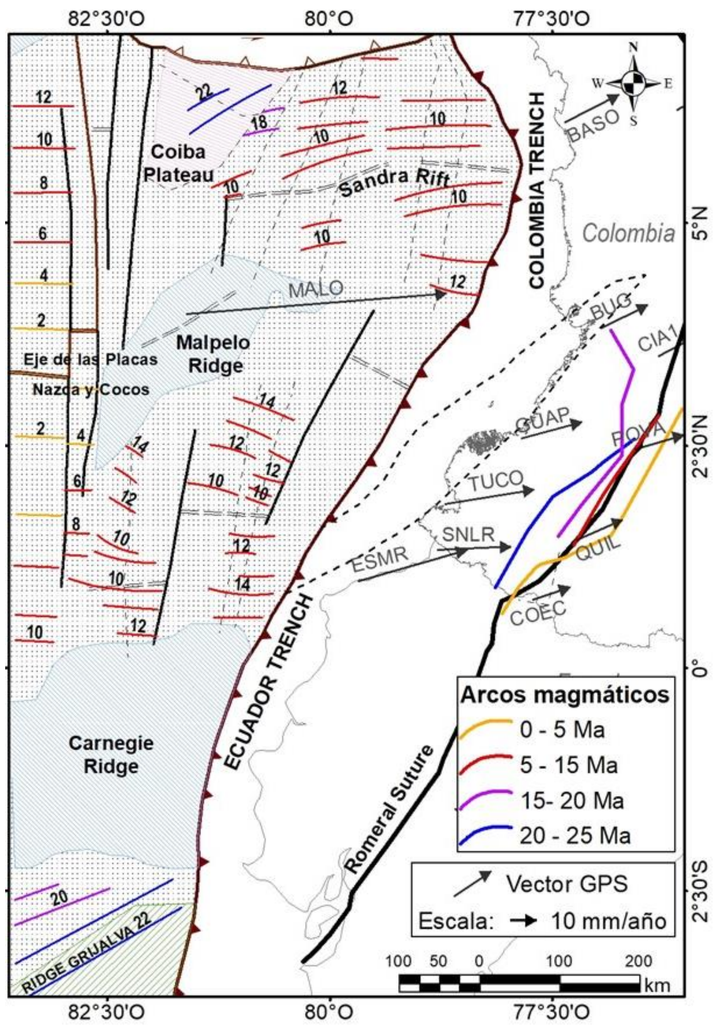


McGirr et al. (2020)

TECTONIC VARIABLES TO CONSIDER FOR THE COLOMBIAN PACIFIC FOREARC BASINS

1. Understanding of the age and geometry of the subducted slab (Farallon, Nazca, Cocos)

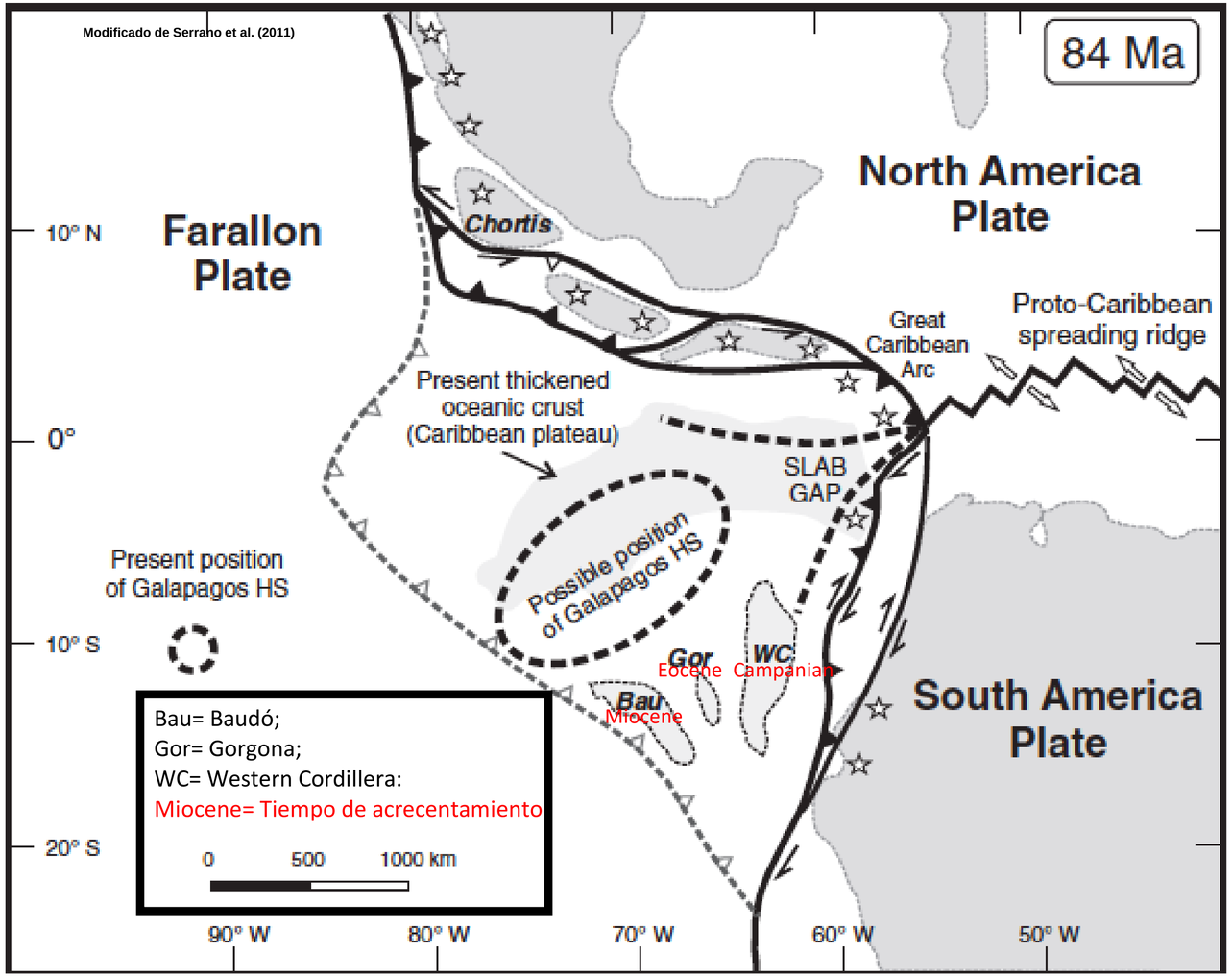
1. Eastward migration of contiental magmatic arc

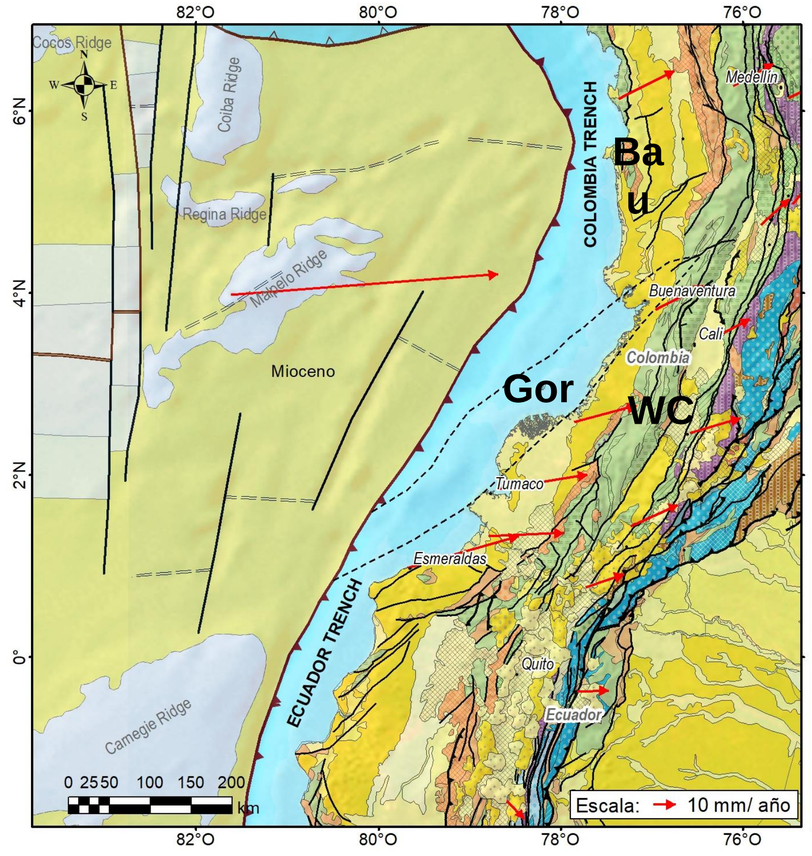


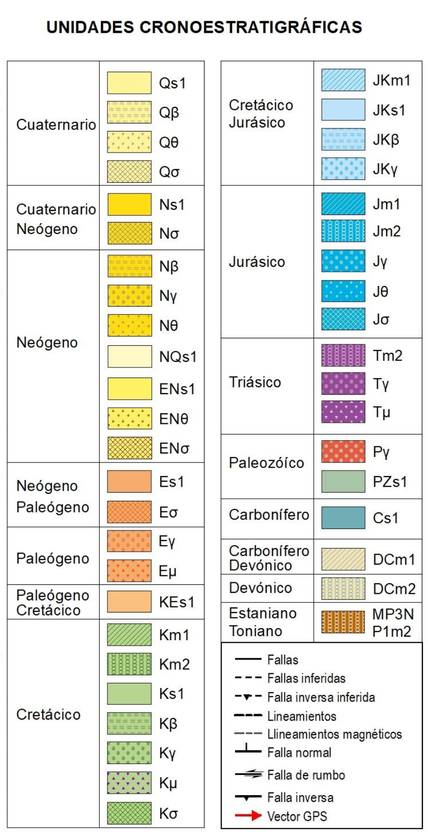
Lonsdale (2005); Mora et al. (2019); Jaramillo et al. (2019); Leal-Mejia et al. (2018)

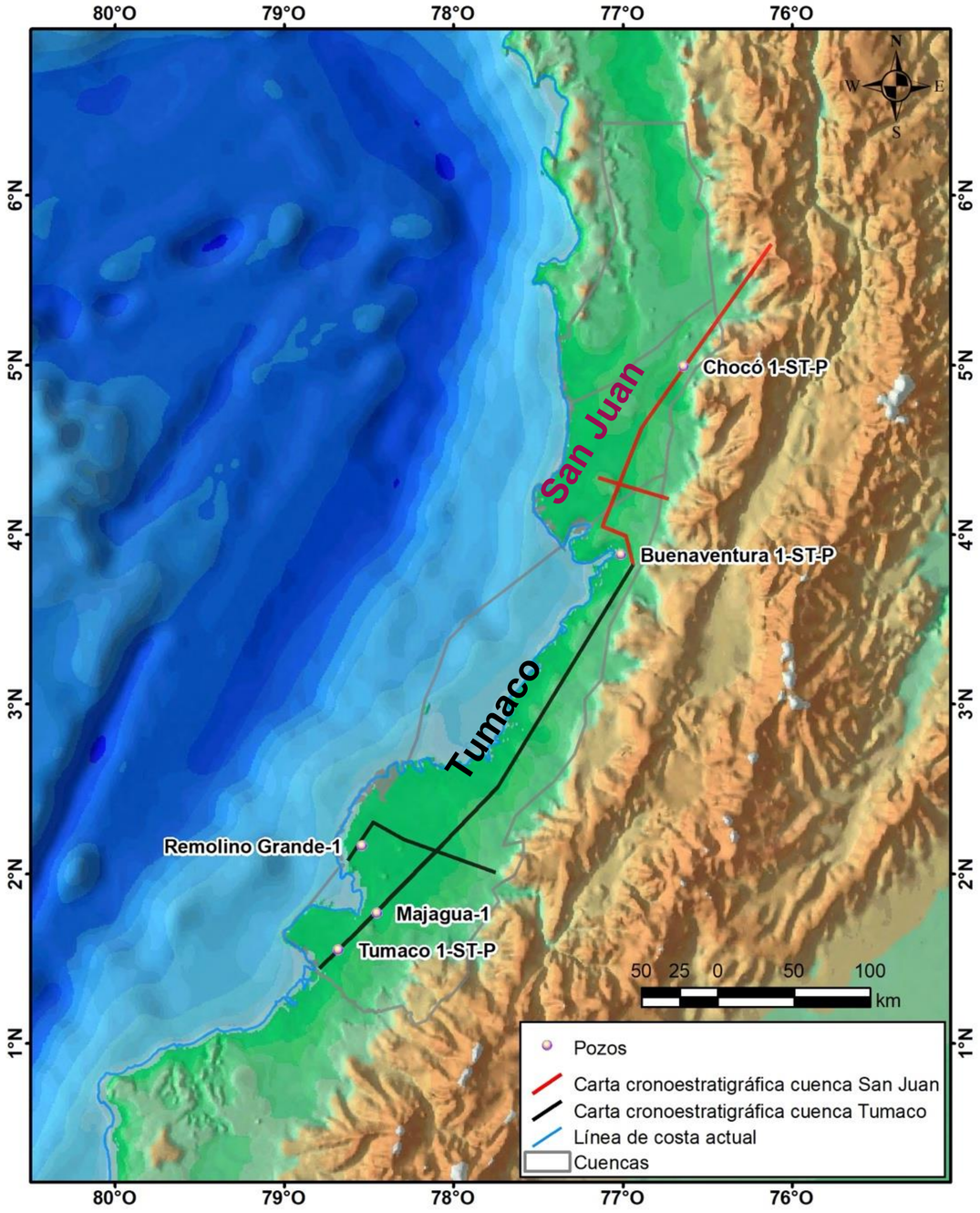
TECTONIC VARIABLES TO CONSIDER FOR THE COLOMBIAN PACIFIC FOREARC BASINS

3. Neogene forearc basin growth upon a complex accretionary margin









CHRONOSTRATIGRAPHIC CHART CONSTRUCTION FOR ONSHORE TUMACO AND SAN JUAN BASINS

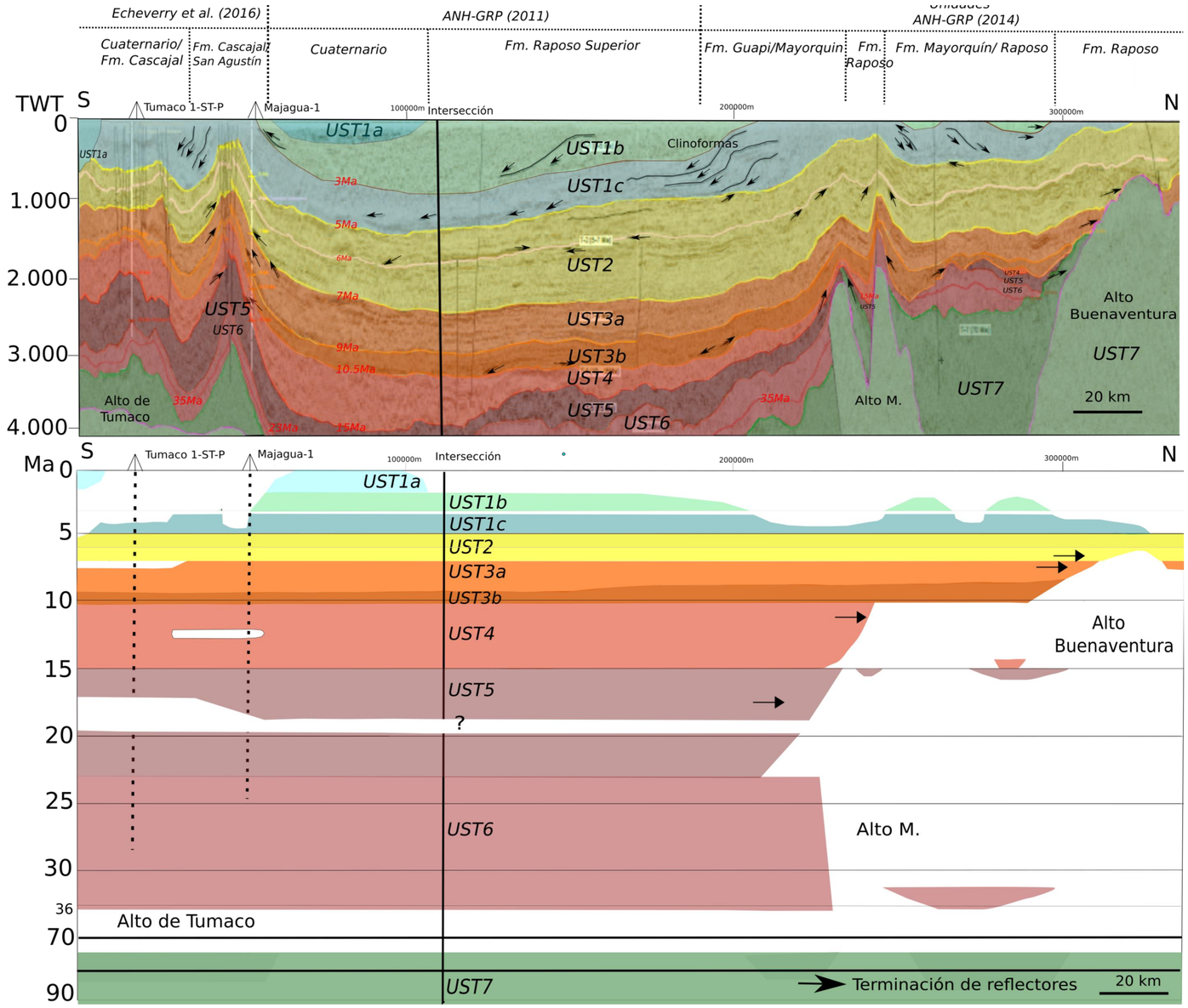
1. Five wells with biostratigraphic control and detailed sedimentological analysis (2010-2020)

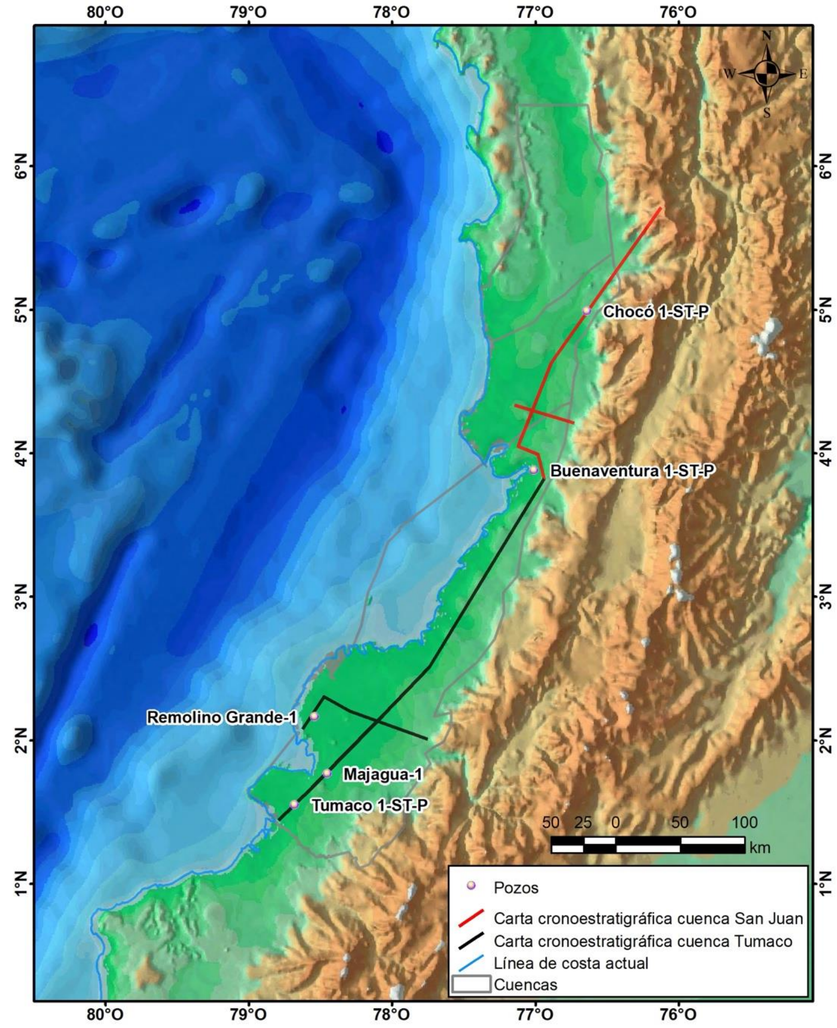
2. Definition of seismic units separated by chronostratigraphic surfaces

3. Definition of basin geometry change during the Neogene

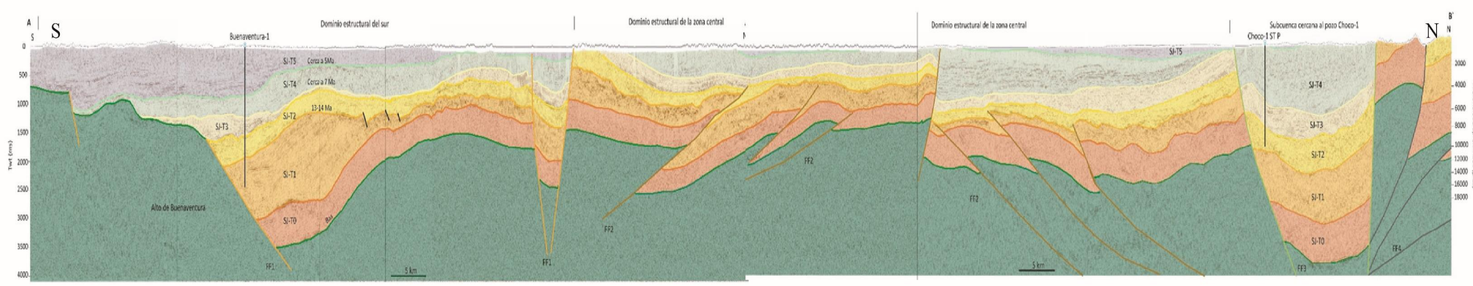
4. Poor definition of seismic units > 15 Ma

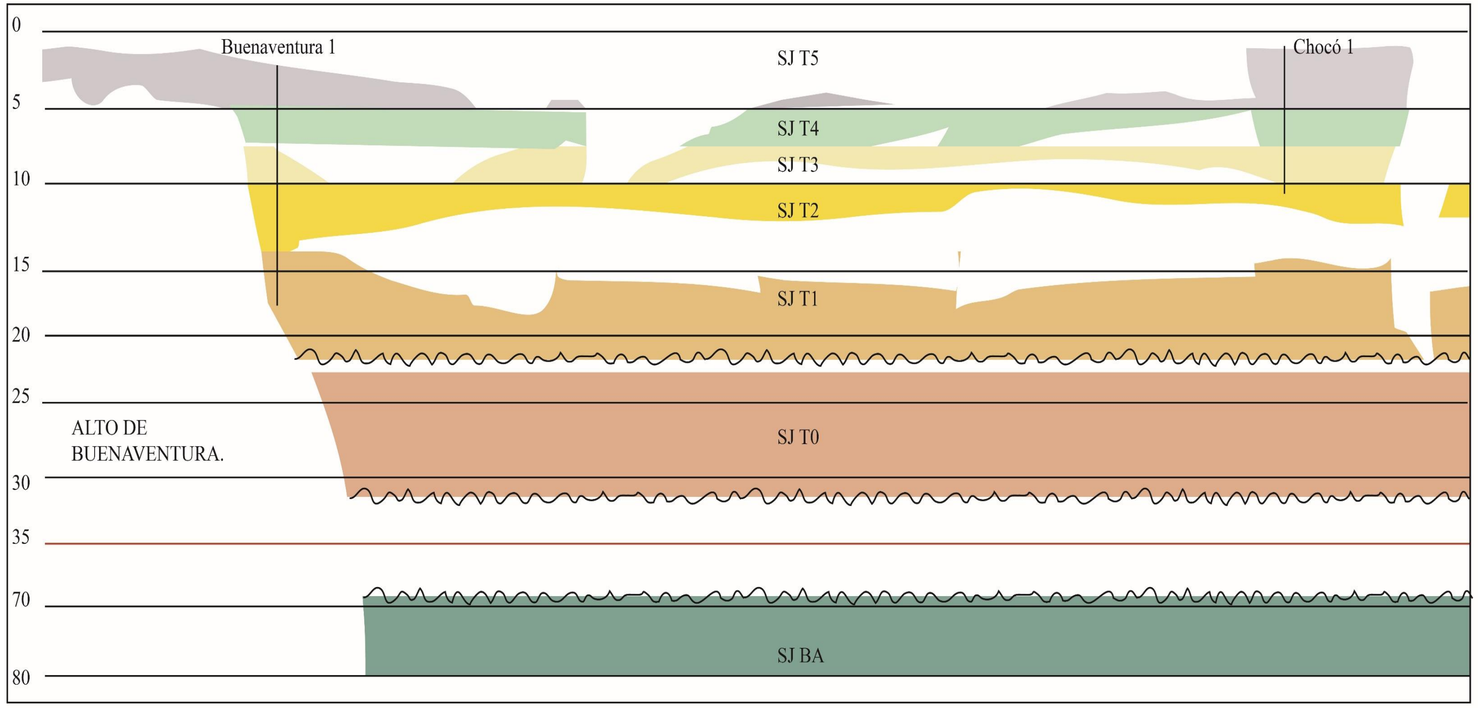
NNE- CHRONOSTRATIGRAPHIC CHART – TUMACO ONSHORE BASIN

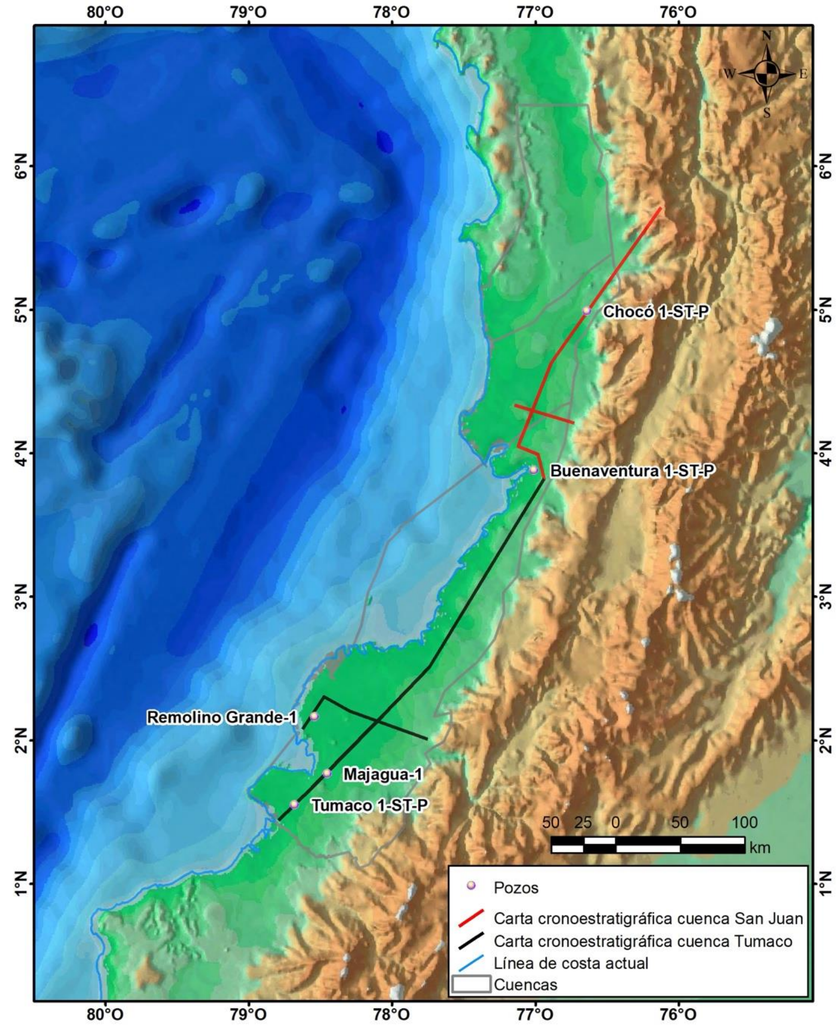




NNE- CHRONOSTRATIGRAPHIC CHART – SAN JUAN ONSHORE BASIN

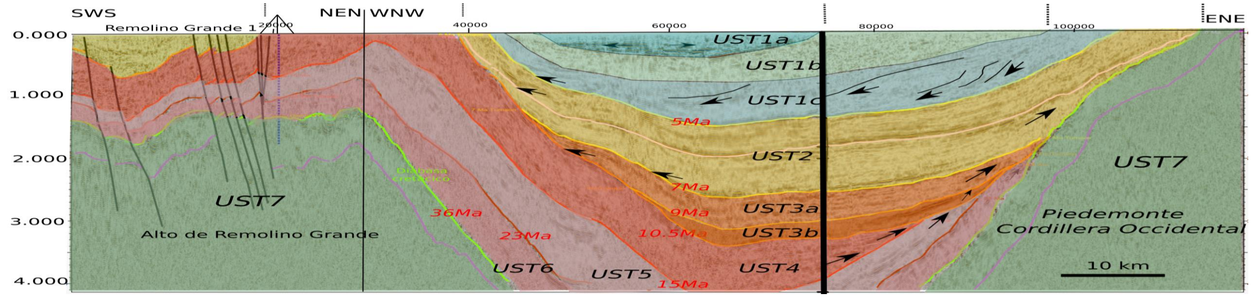


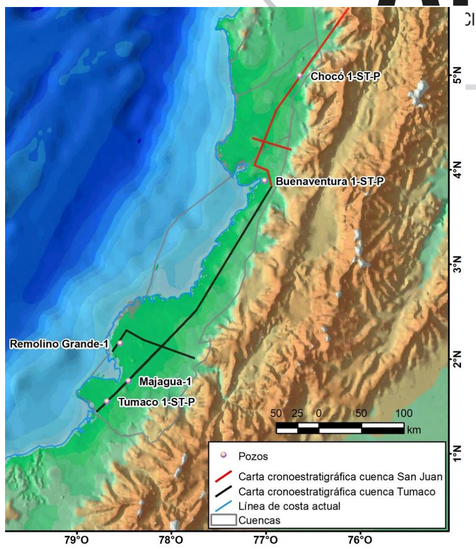




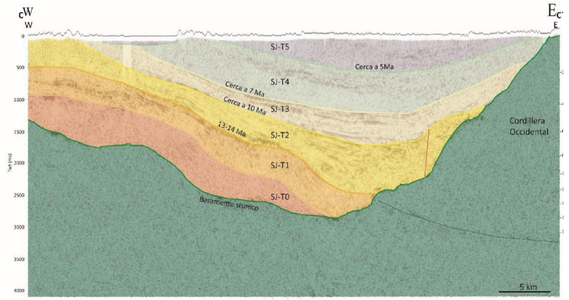
E-W CHRONOSTRATIGRAPHIC CHARTS

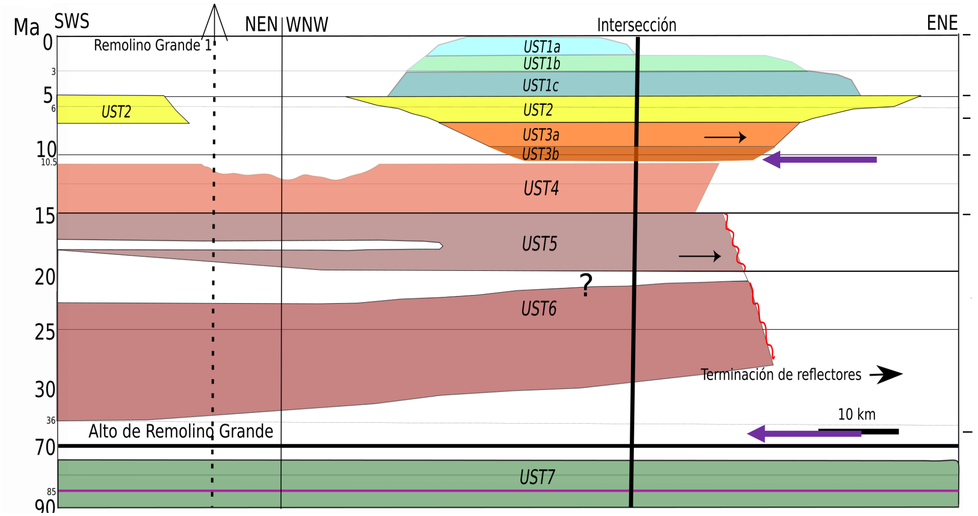
TUMACO ONSHORE BASIN (> 8.2 km thick)





SAN JUAN ONSHORE BASIN





0 Ma — UST1 = SJT5

5 Ma — UST2 = SJT4

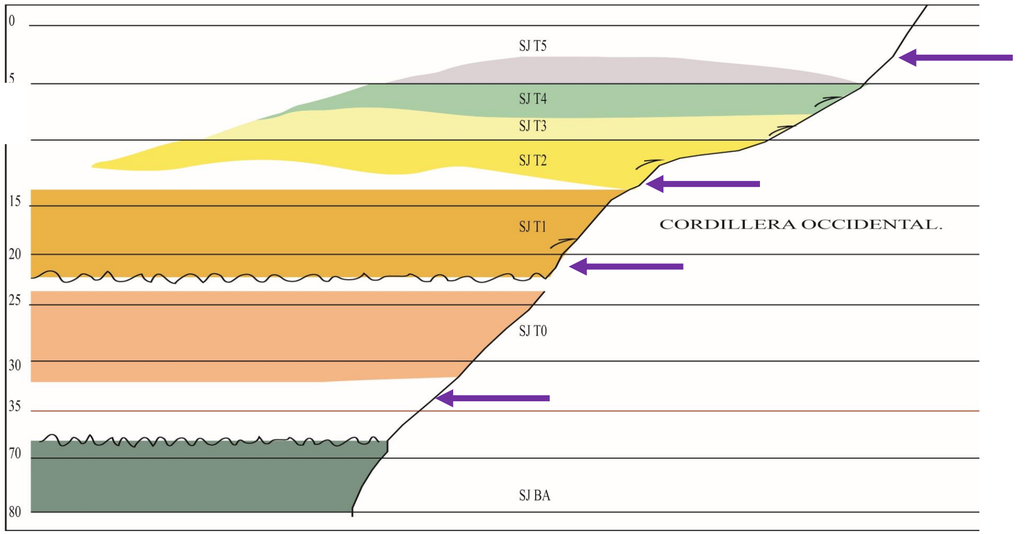
7 Ma — UST3 = SJT3

10.5 Ma — UST4 = SJT2

15 Ma — UST5 = SJT1

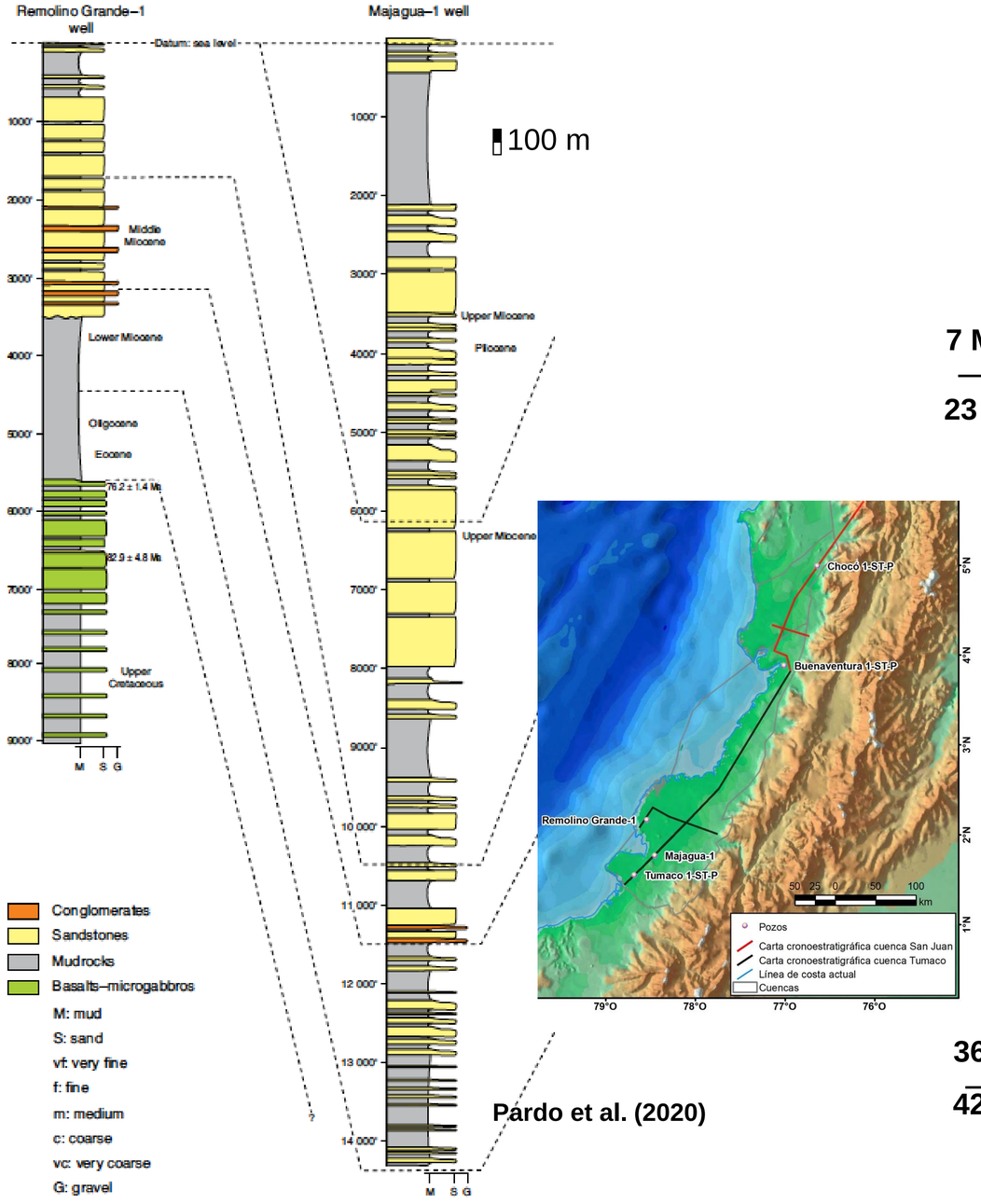
23 Ma — UST6 = SJT0

37 Ma — UST7 = SJBA



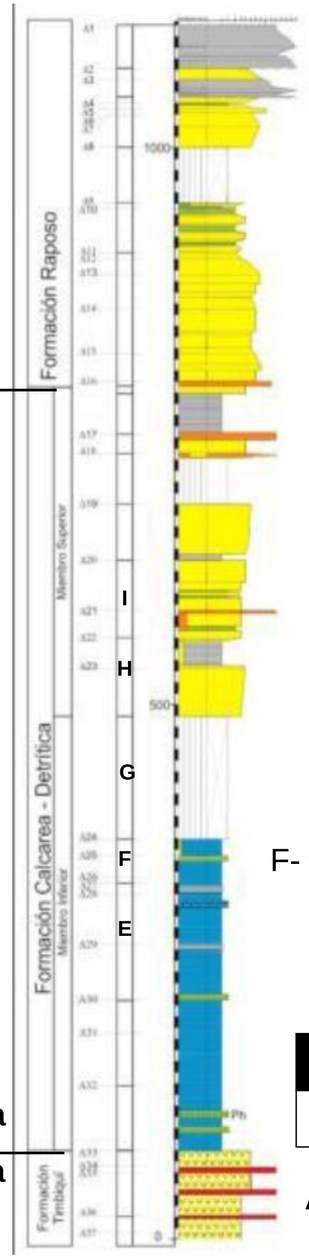
DEFORMATION EVENT

WESTERN MARGIN OF THE TUMACO ONSHORE BASIN



Pardo et al. (2020)

WESTERN FOOTHILLS OF THE WESTERN CORDILLERA



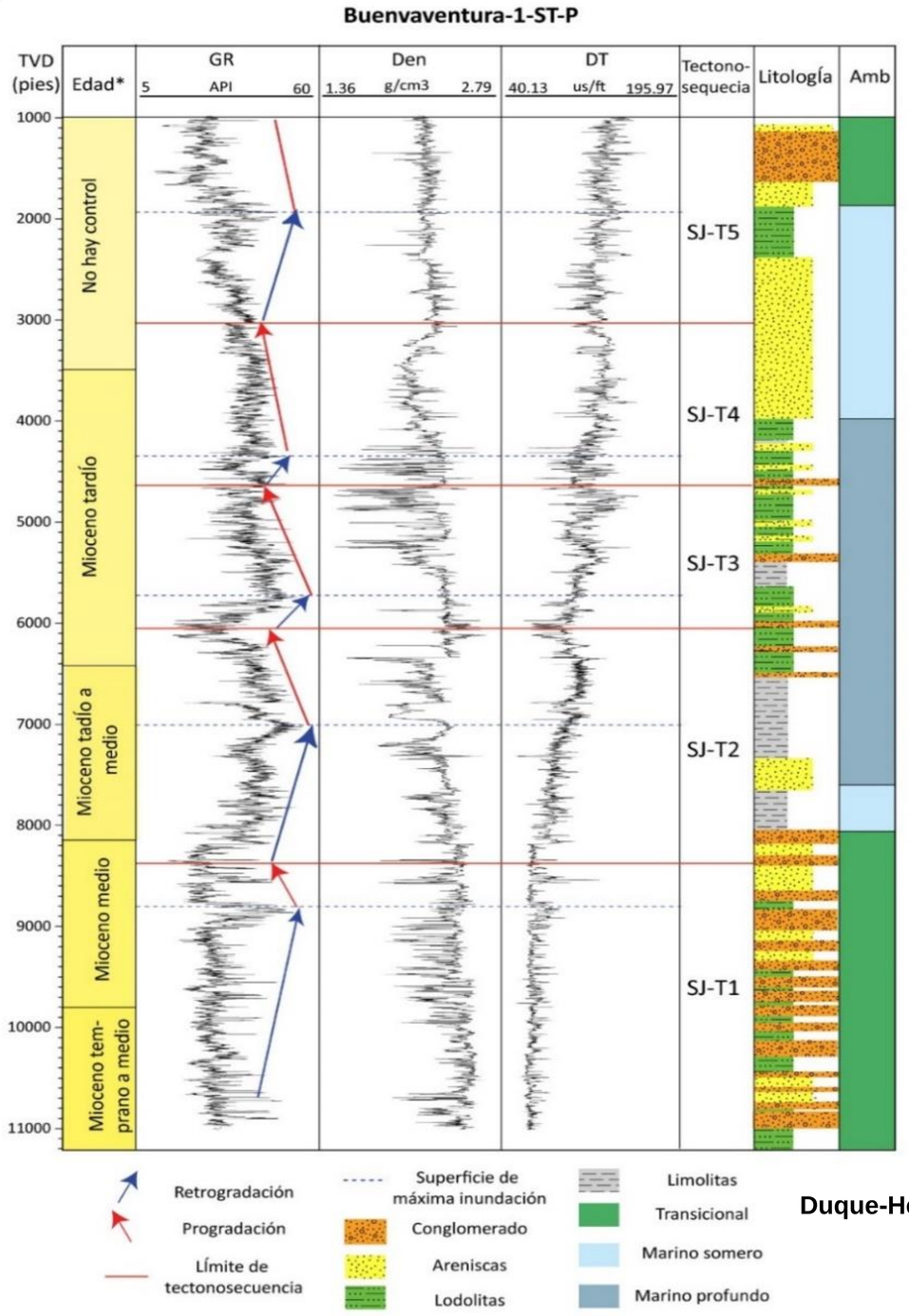
ANH-GRP (2014)

STRATIGRAPHIC SUCCESSION

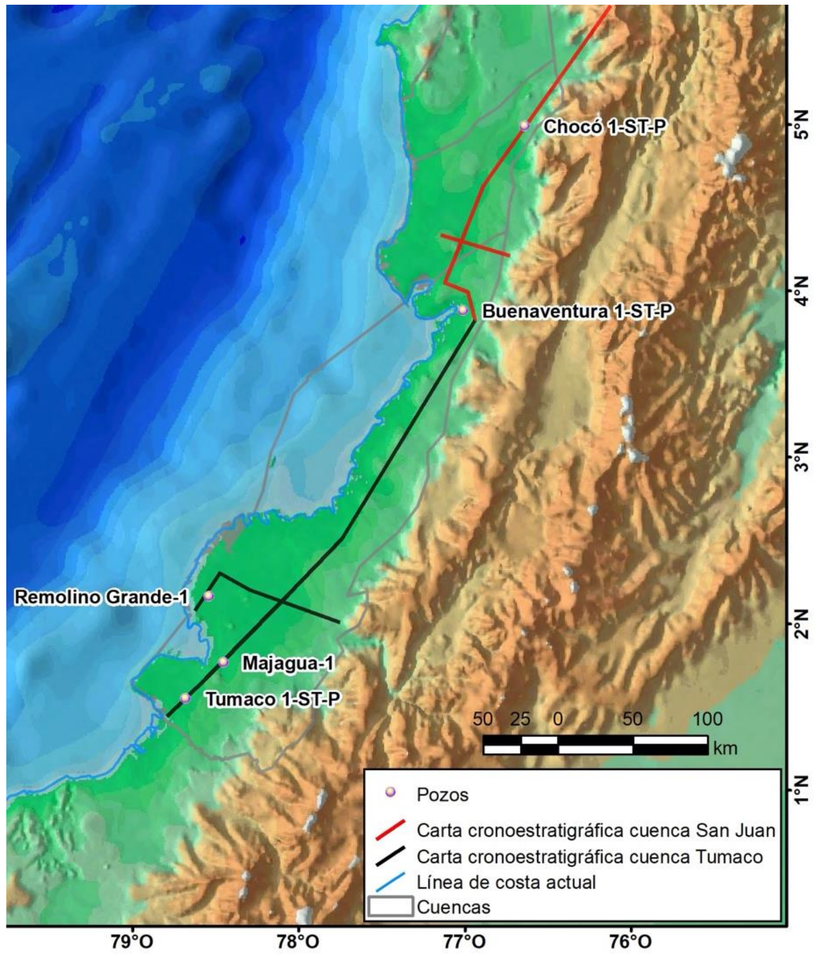
1. **Possible source rocks of Upper Cretaceous and upper Eocene – Oligocene age**
2. **Most proximal lithofacies of reservoir units to the west;**
3. **conglomeratic and sandy intervals in the western margin of the onshore basin**

F- volcanoclastic fragments 37-33 Ma (Bineli-Betsy et al., 2017)

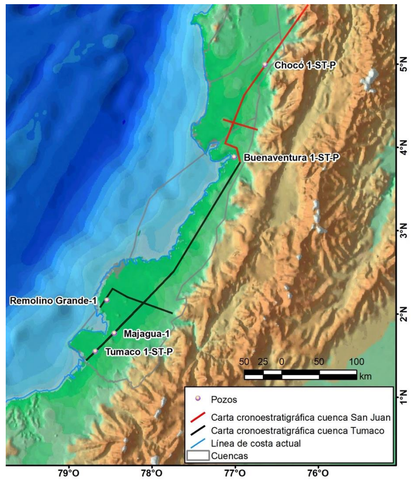
STRATIGRAPHIC SUCCESSION OF THE SOUTHERN SAN JUAN BASIN



Duque-Herrera et al. (2018))

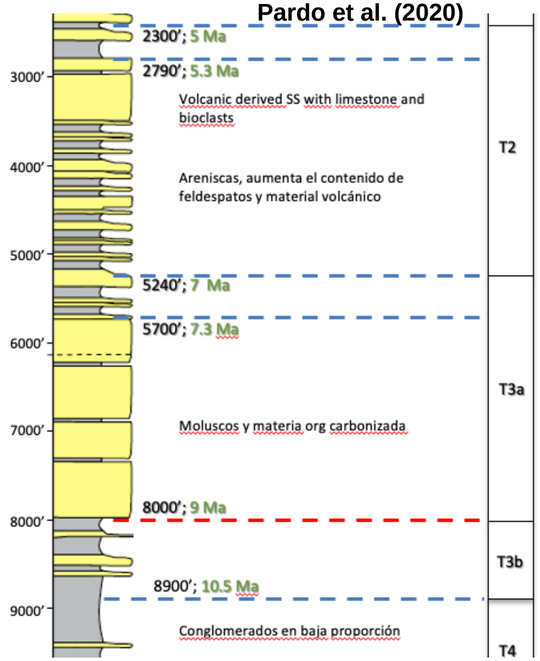


GEOMETRY OF RESERVOIR UNITS
NNE- REGIONAL CORRELATION
TUMACO ONSHORE BASIN



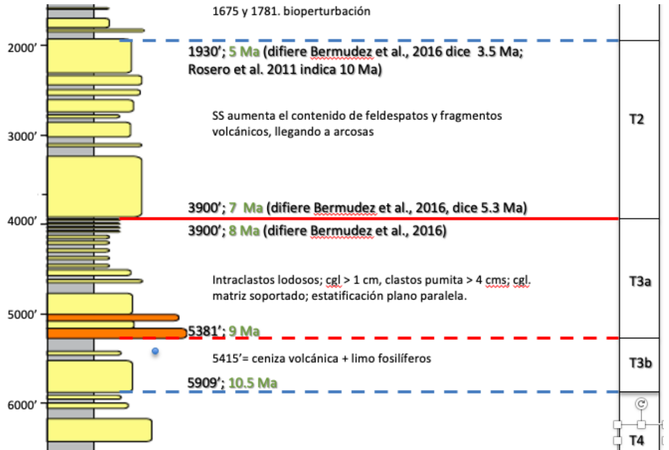
Majagua-1

Pardo et al. (2020)

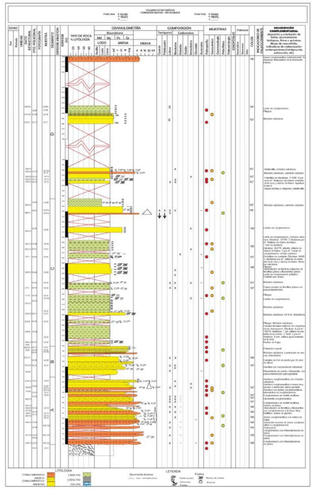


Tumaco 1-ST-P

Pardo et al. (2020)



ANH-GRP (2011) – 1400 m



ANH-GRP (2014) – 1000 m

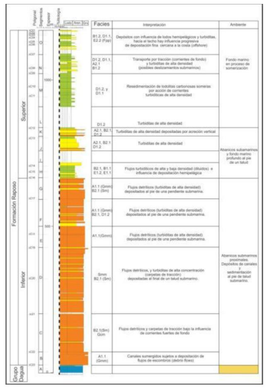
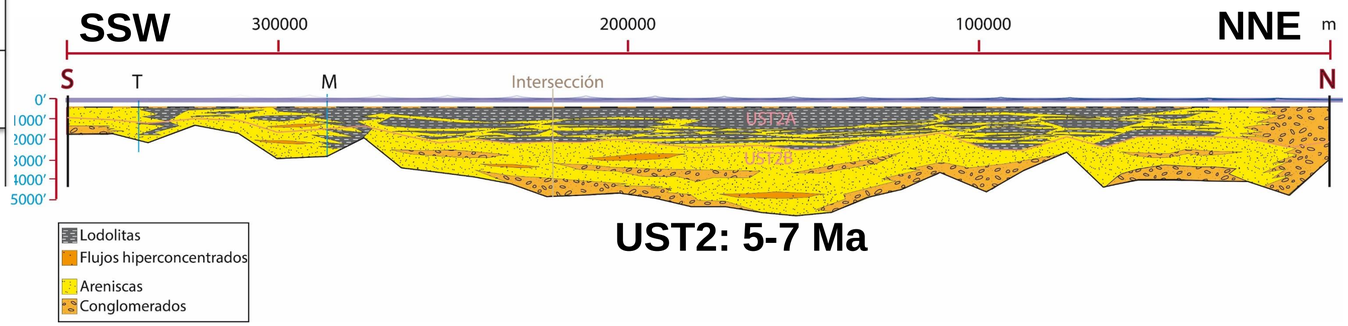
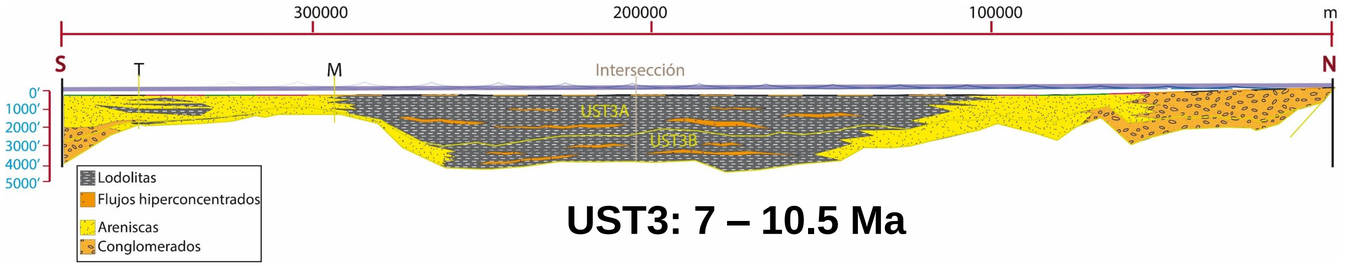


Figura 4-35. Columna de la sección del río Cajambre y los ambientes interpretados en este estudio.



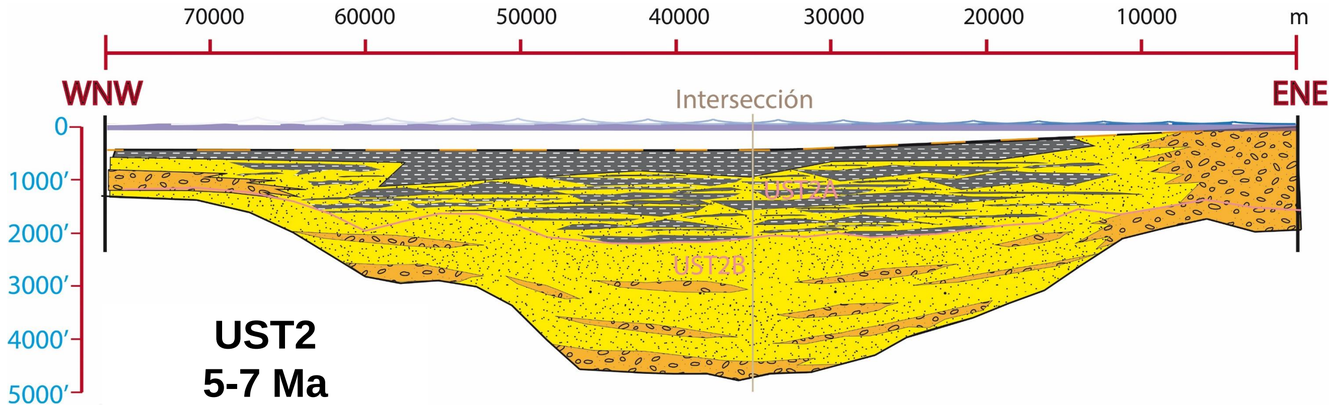
UST2: 5-7 Ma

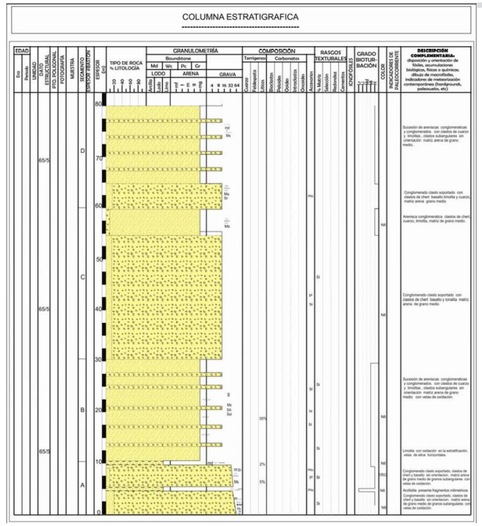


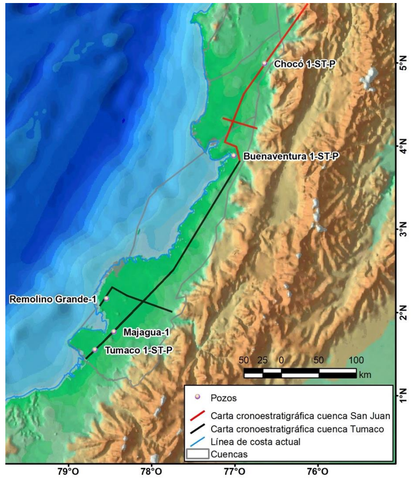
UST3: 7 – 10.5 Ma

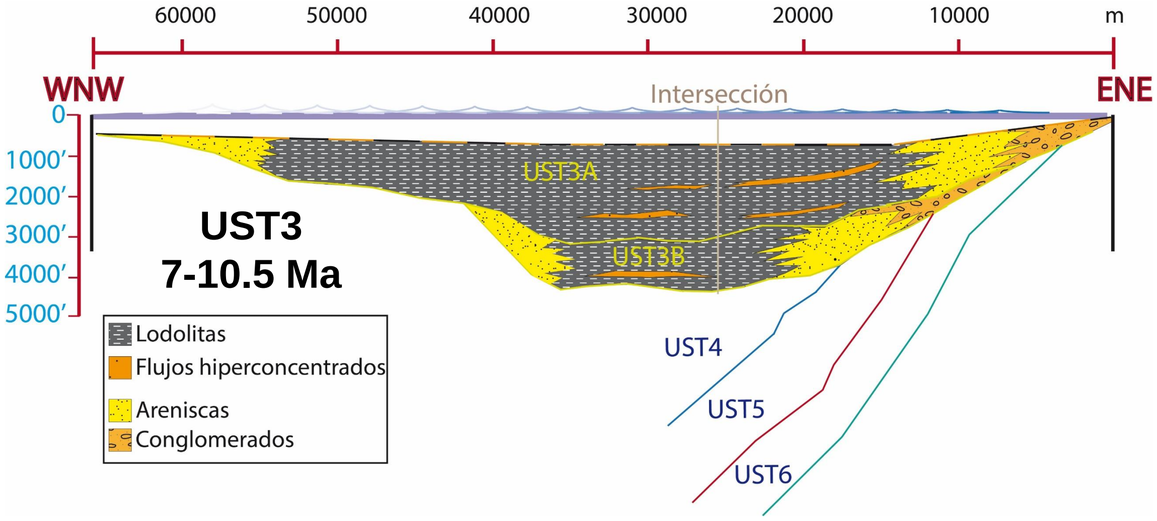
GEOMETRY OF RESERVOIR UNITS

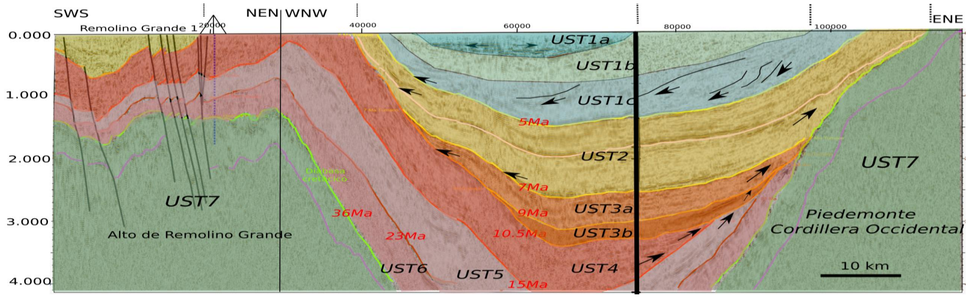
W-E REGIONAL CORRELATION
TUMACO ONSHORE BASIN





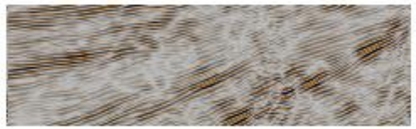
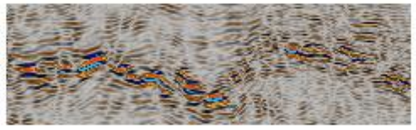
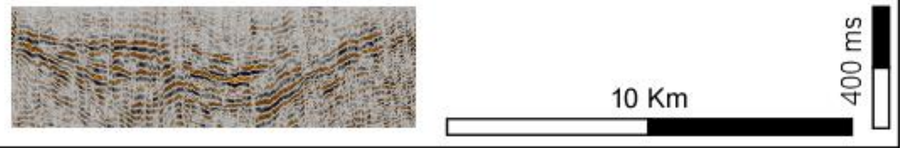




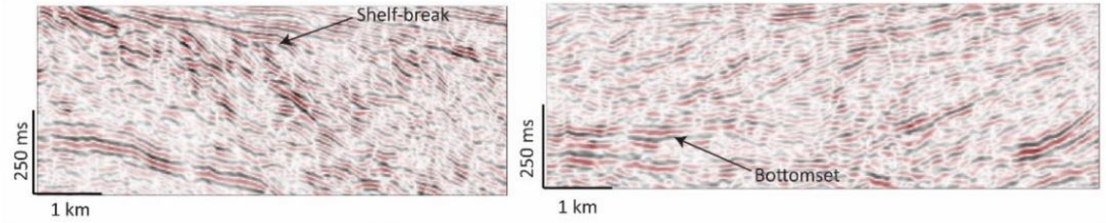
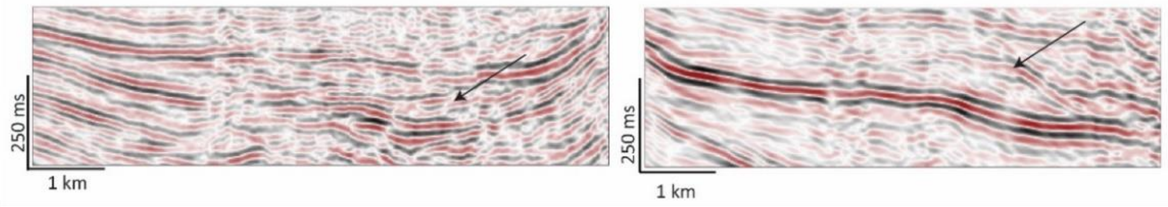
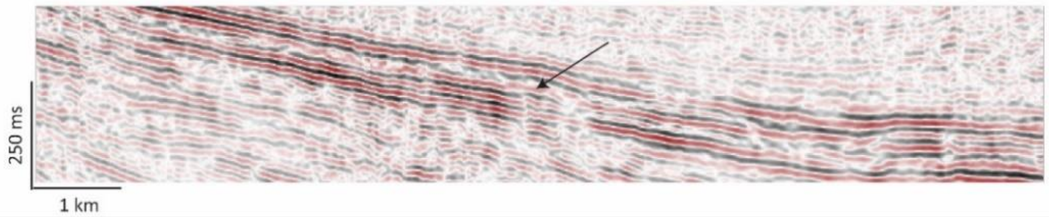
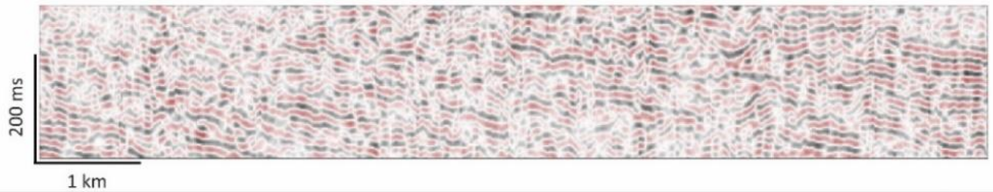
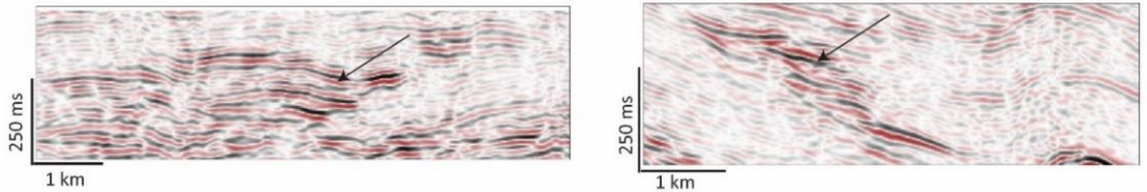


ANH-GRP (2011)

SEISMIC FACIES – TUMACO ONSHORE BASIN

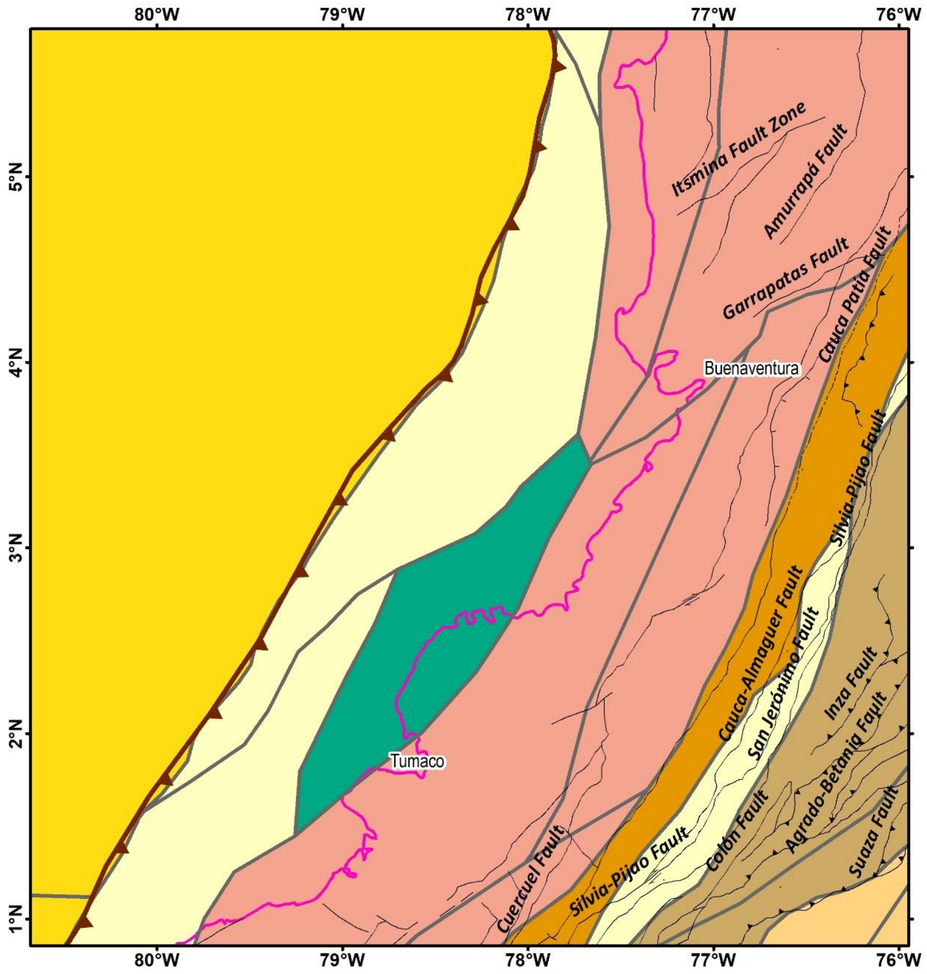
Descripción Facies	Interpretación	Ejemplos
Facies de clinoformas con downlaps y toplaps y bottomsets continuos de alta amplitud	Depósitos deltáicos de plataforma superior	
Facies de reflectores continuos de alta y media amplitud	Depositos de plataforma marina somera	
Facies de reflectores discontinuos de alta amplitud haciendo onlap	Abanicos aluviales ó abanicos submarinos.	
Facies de reflectores discontinuos de amplitudes variables, toplaps erosivos	Depositos de plataforma externa y talud superior	
Facies de reflectores continuos de baja amplitud con bottomsets concavos de alta amplitud haciendo onlap	Depositos de plataforma externa y turbiditas axiales	
Facies de alta amplitud muy discontinuas	Rocas volcánicas fracturadas	
Facies de amplitud vari-able, discontinuas, onlap	Canales fluviales	

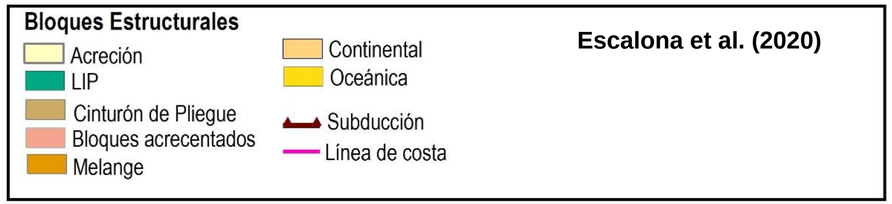
SEISMIC FACIES – SAN JUAN ONSHORE BASIN

Facies description	Interpretation	Example
Clinoforms with a height of more than 150 m, high amplitude bottomsets can be present	Shelf margin clinoforms. Deltas prograding in an outer shelf to upper slope. In the bottomsets, turbidites can be present	
Wedges located close to a slope or fault	Alluvial fans, or other fans tectonically controlled deposited in a marine environment.	
Continuous, high to medium amplitude reflectors	Marine, platform?	
Disontinuous, medium to low amplitude reflectors. Locally, they can have high amplitude	Continental	
Disontinuous, high amplitude reflectors	Channels?	

PALEOGEOGRAPHIC RECONSTRUCTION

1. Structural blocks that were accreted since Late Cretaceous time

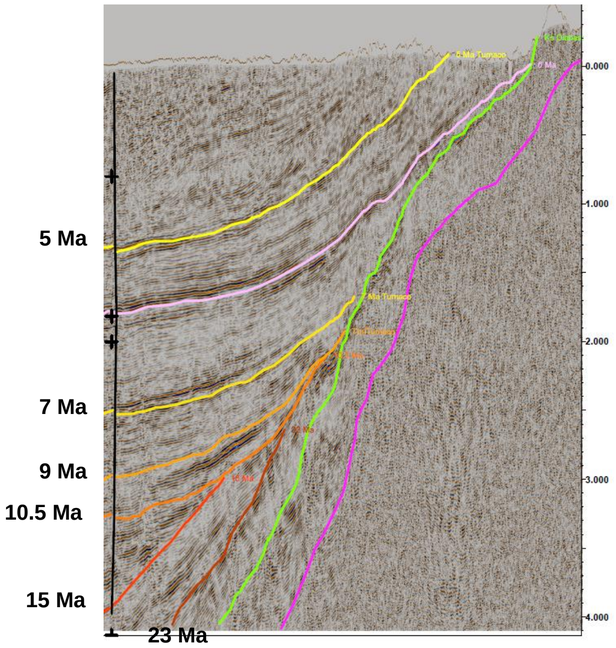




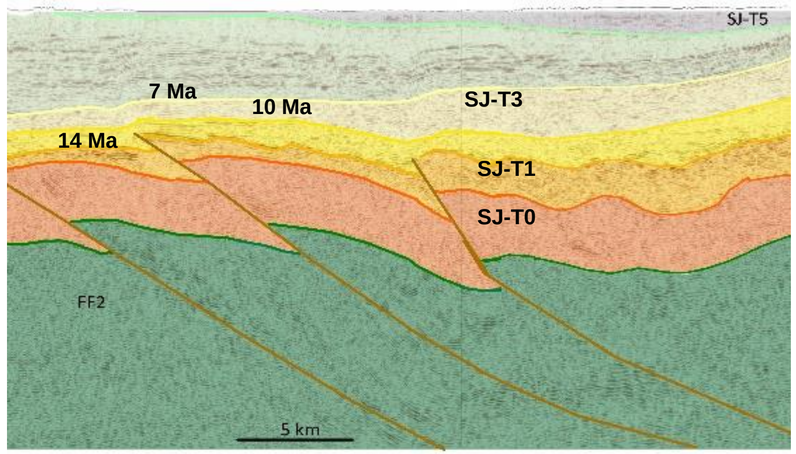
Escalona et al. (2020)

2. Timing of Neogene deformation

Tumaco onshore

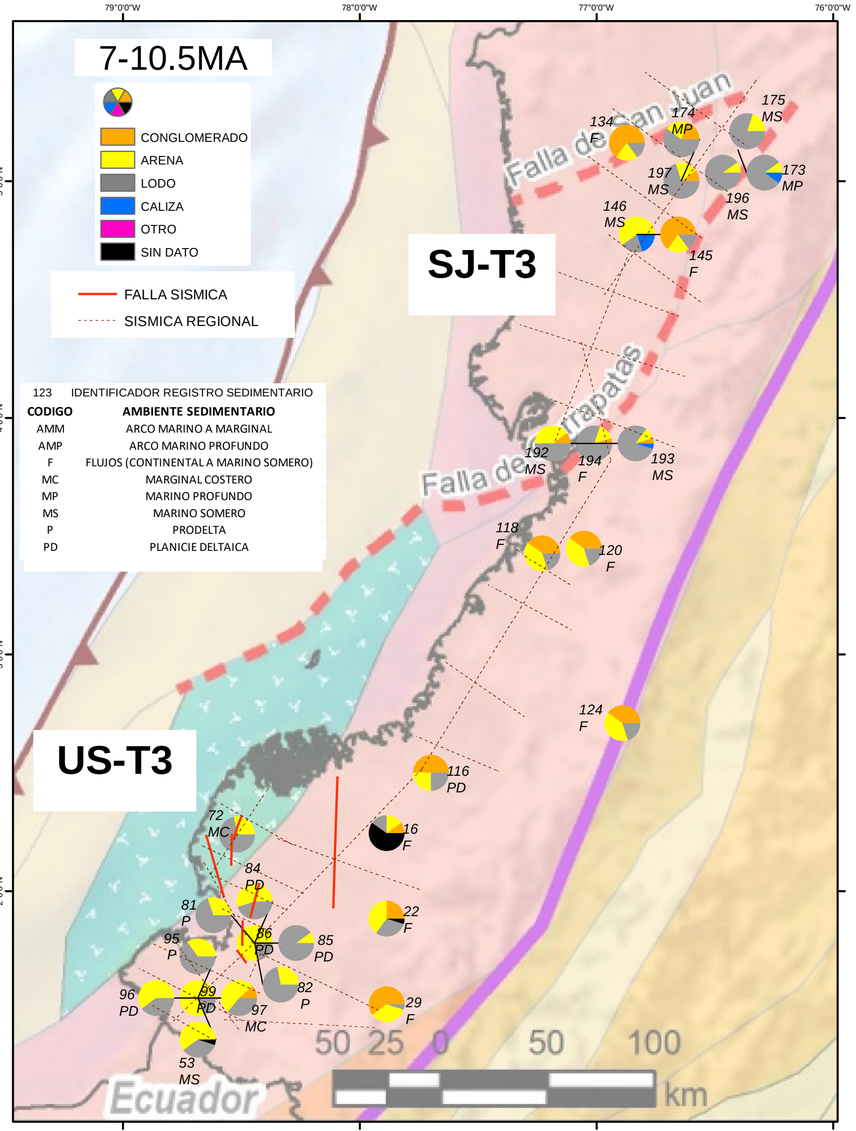


San Juan onshore

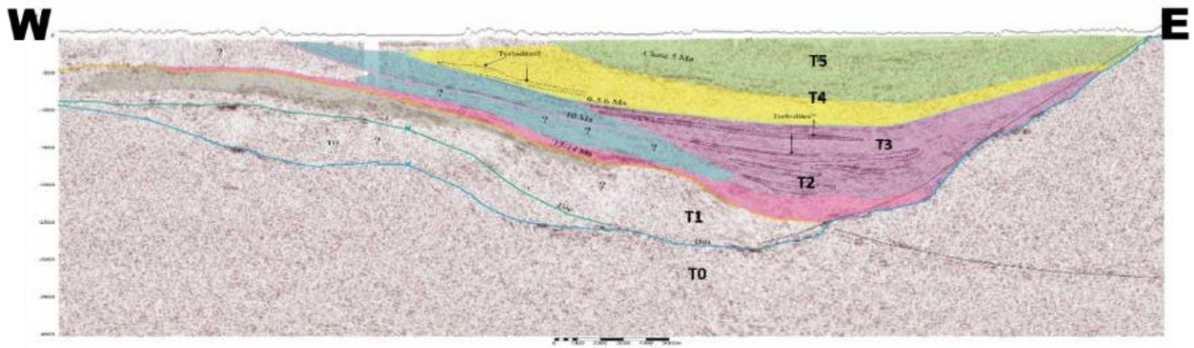


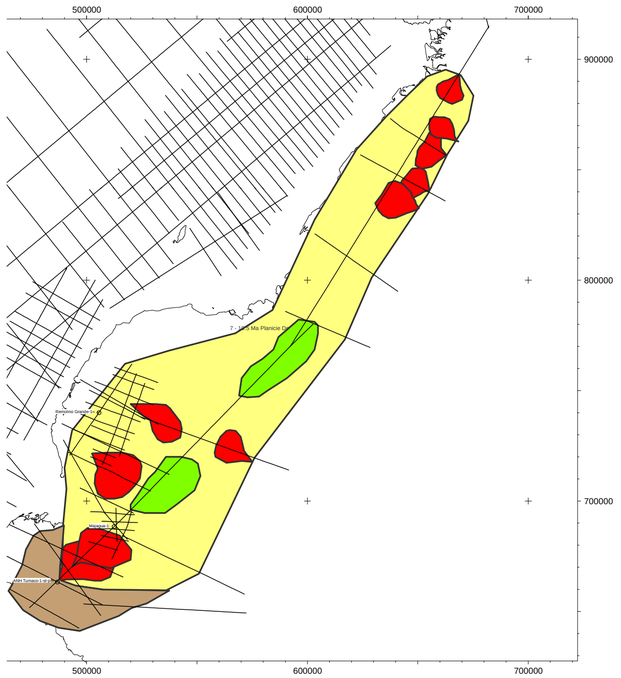
PALEOGEOGRAPHIC RECONSTRUCTION

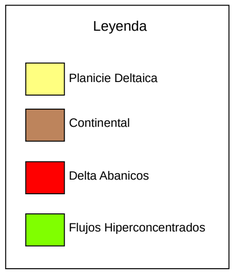
3. Lithofacies and depositional environment interpetation from surface and subsurface data



4. Lateral changes of seismic facies in speh and map views

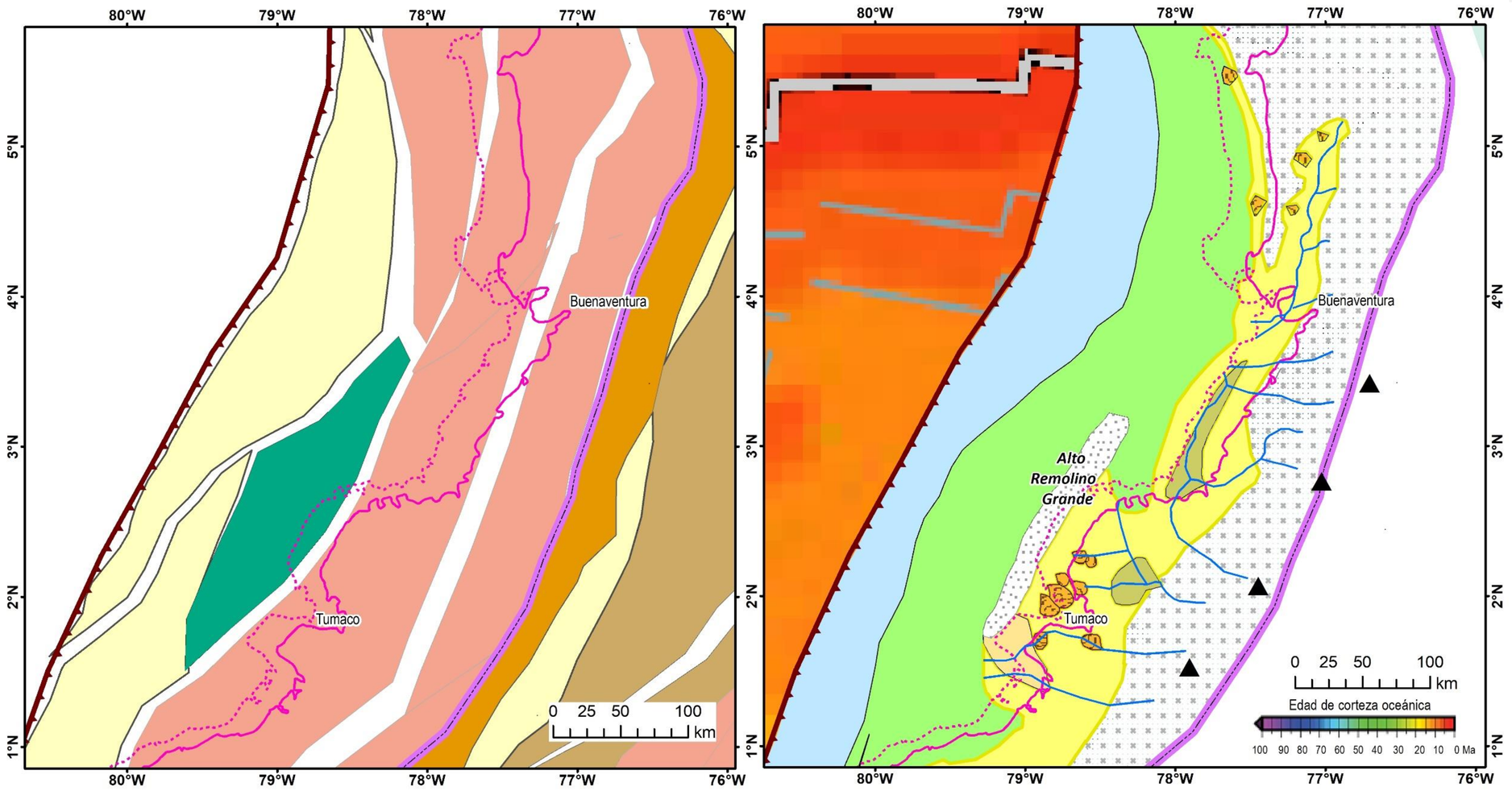






7 - 10.5 Ma

PALEOGEOGRAPHIC RECONSTRUCTION 0 – 5 Ma



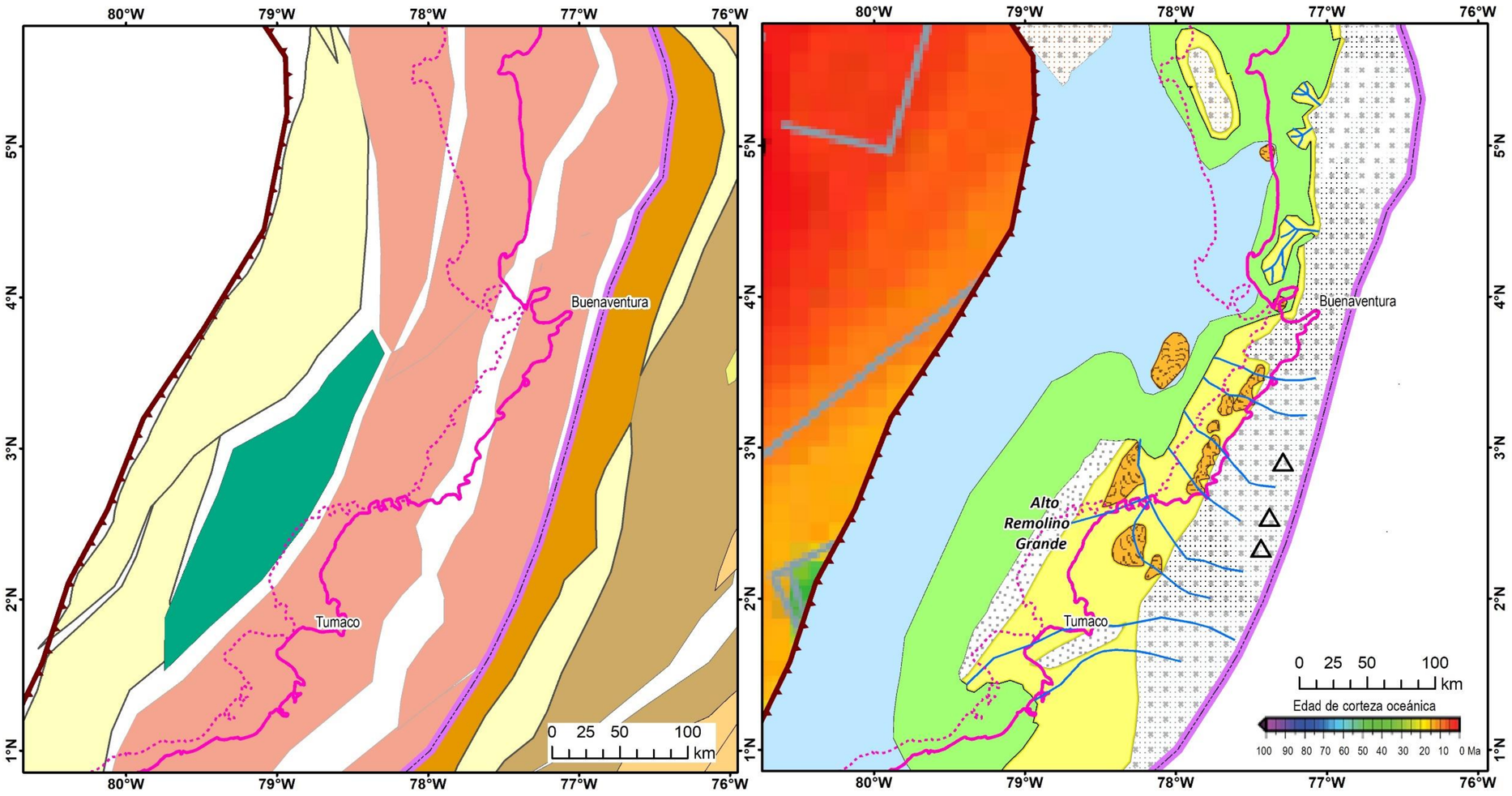
Restauración Palinspástica 0-5 Ma

- Acreción
- LIP
- Cinturón de Pliegue
- Bloques Acrecentados
- Melange
- Continental
- Subducción de 0-5 Ma
- Sutura de Romeral de 0-5 Ma
- Línea de costa 0-5 Ma
- Línea de costa actual

Paleogeografía de 0-5 Ma

- Área positiva
- Alto con pobre a nula exposición subaérea
- Frente deltáico
- Flujos gravitacionales
- Desembocadura de canal
- Fluvial, deltaico y costero
- Marino somero
- Marino profundo y talud
- Arco magmático de 0-5 Ma
- Subducción de 0-5 Ma
- Sutura de Romeral de 0-5 Ma
- Drenajes de 0-5 Ma
- Línea de costa 0-5 Ma
- Línea de costa actual

PALEOGEOGRAPHIC RECONSTRUCTION 5 – 7 Ma



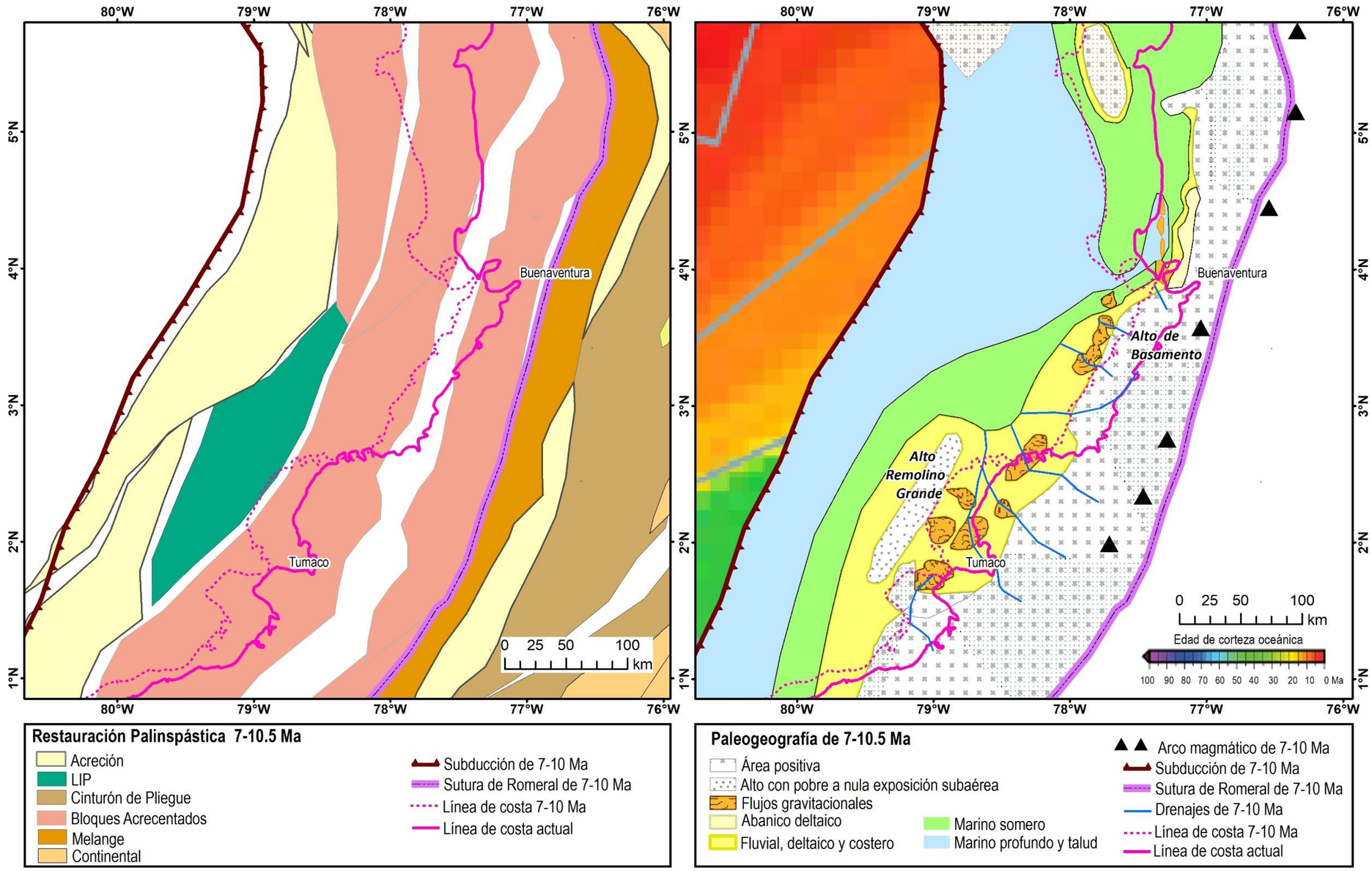
Restauración Palinspástica de 5-7 Ma

- Acreción
- LIP
- Cinturón de Pliegue
- Bloques Acrecentados
- Melange
- Continental
- Subducción de 5-7 Ma
- Sutura de Romeral de 5-7 Ma
- Línea de costa 5-7 Ma
- Línea de costa actual

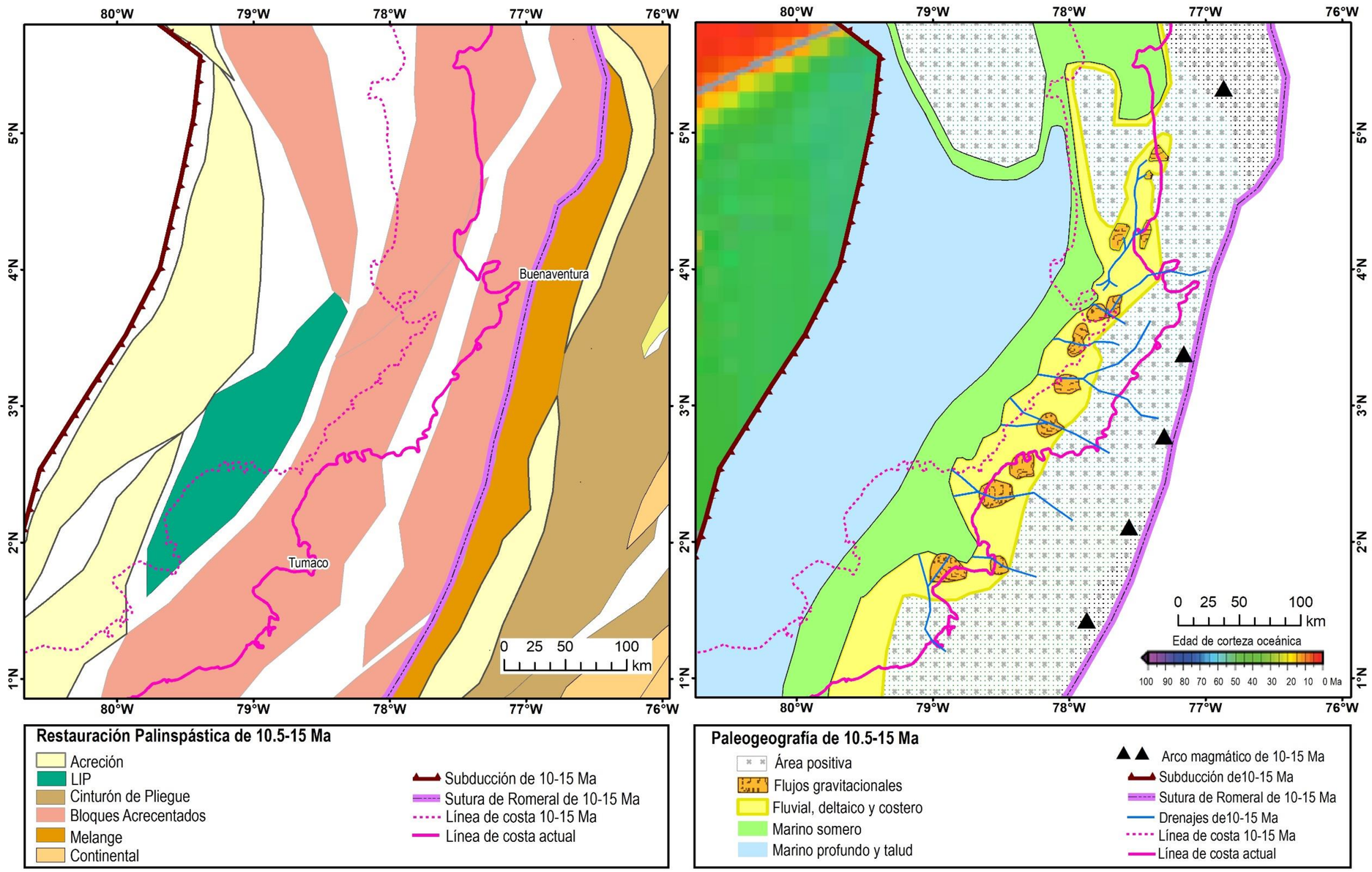
Paleogeografía de 5-7 Ma

- Área positiva
- Alto con pobre a nula exposición subaérea
- Flujos gravitacionales
- Fluvial, deltaico y costero
- Marino somero
- Marino profundo y talud
- Subducción de 5-7 Ma
- Sutura de Romeral de 5-7 Ma
- Drenajes de 5-7 Ma
- Línea de costa 5-7 Ma
- Línea de costa actual
- Arco magmático extinto de 5-7 Ma

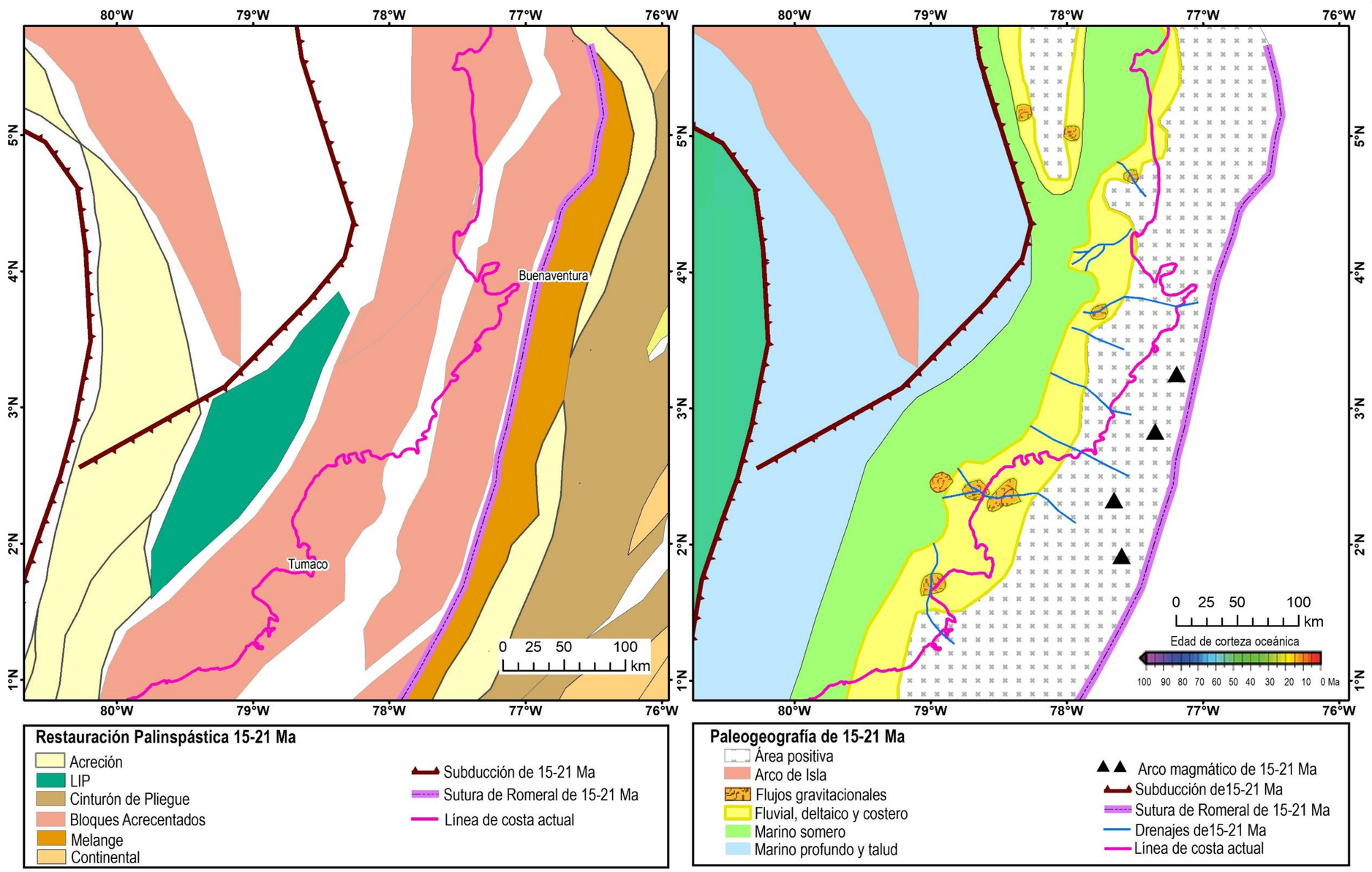
PALEOGEOGRAPHIC RECONSTRUCTION 7 – 10,5 Ma



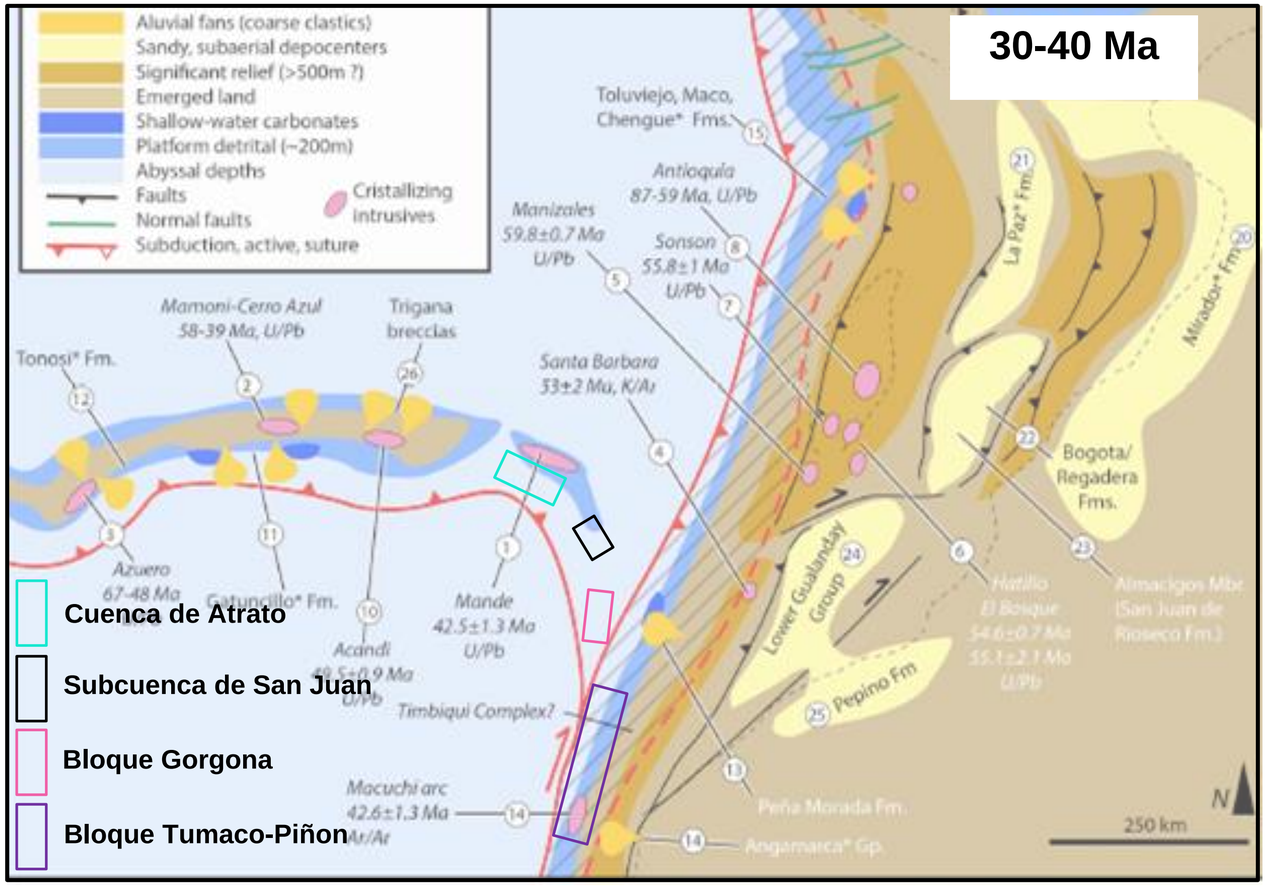
PALEOGEOGRAPHIC RECONSTRUCTION 10,5 – 15 Ma



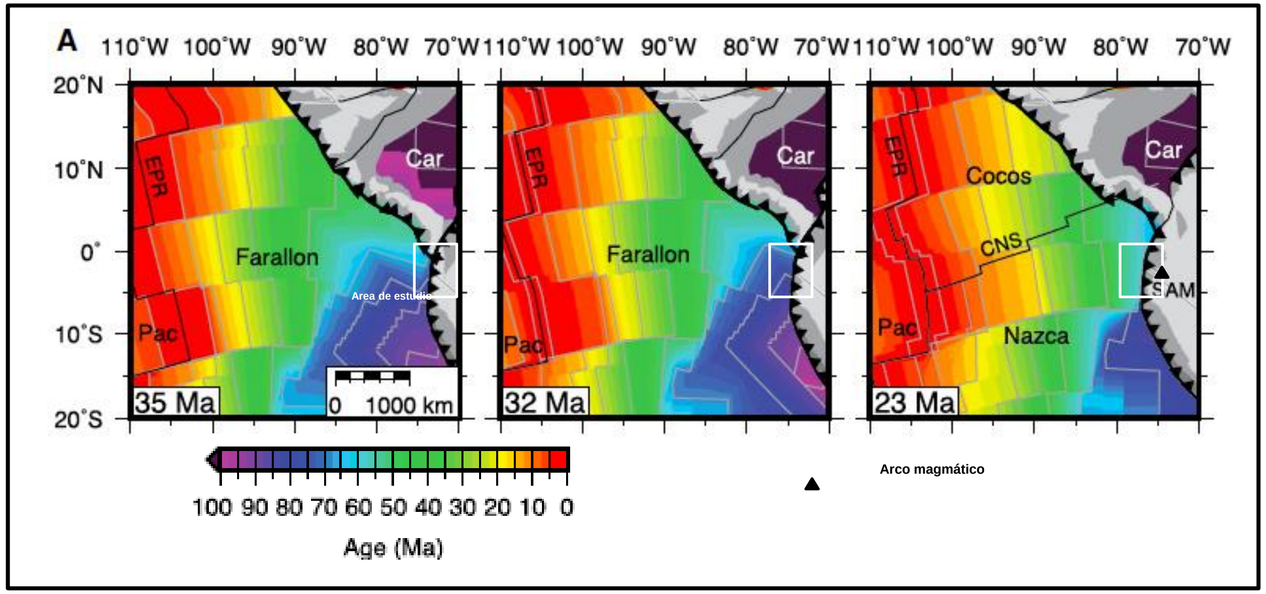
PALEOGEOGRAPHIC RECONSTRUCTION 15 – 23 Ma



PALEOGEOGRAPHIC RECONSTRUCTION 23 – 40 Ma



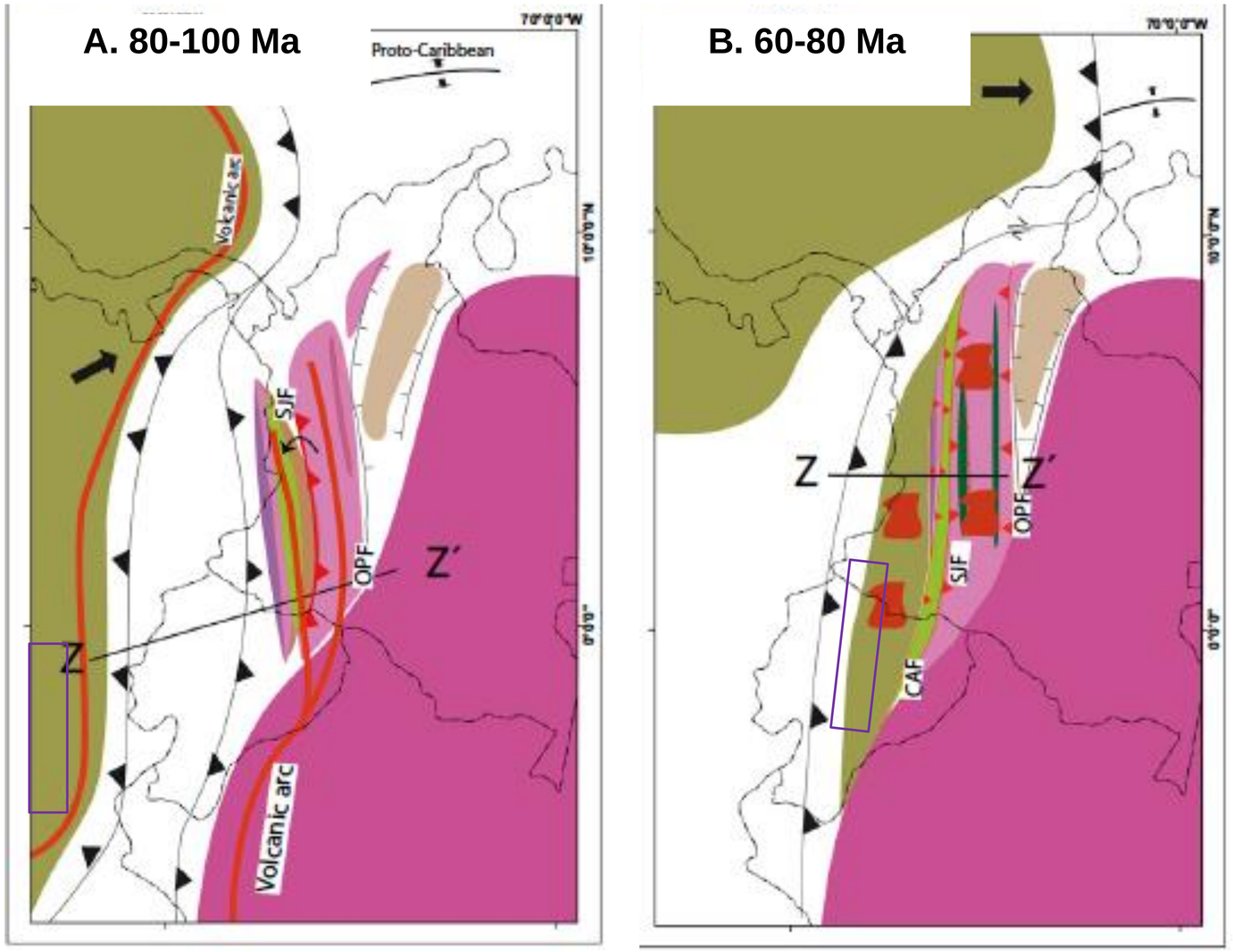
Cardona et al. (2018)



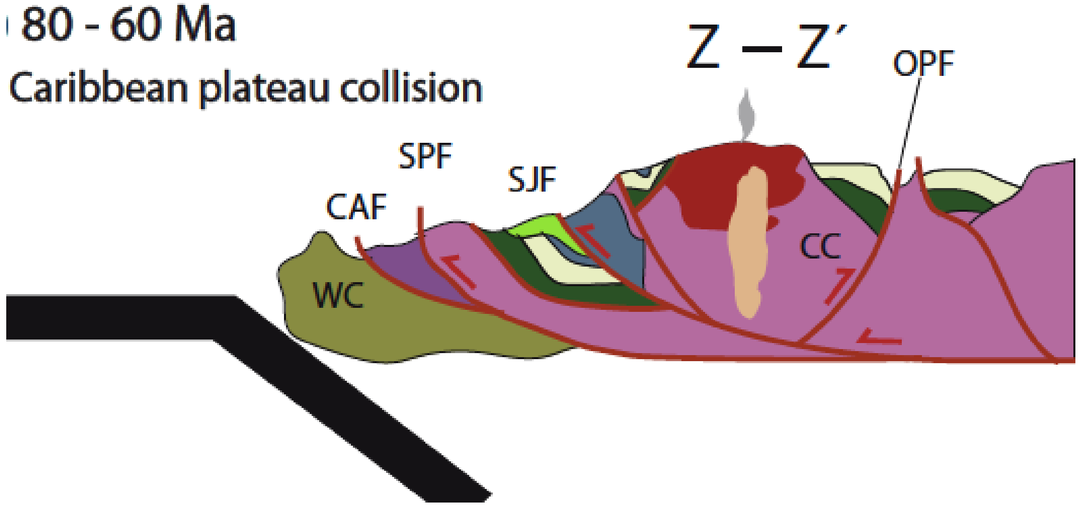
McGirr et al. (2020)

PALEOGEOGRAPHIC RECONSTRUCTION 40 – 80 Ma

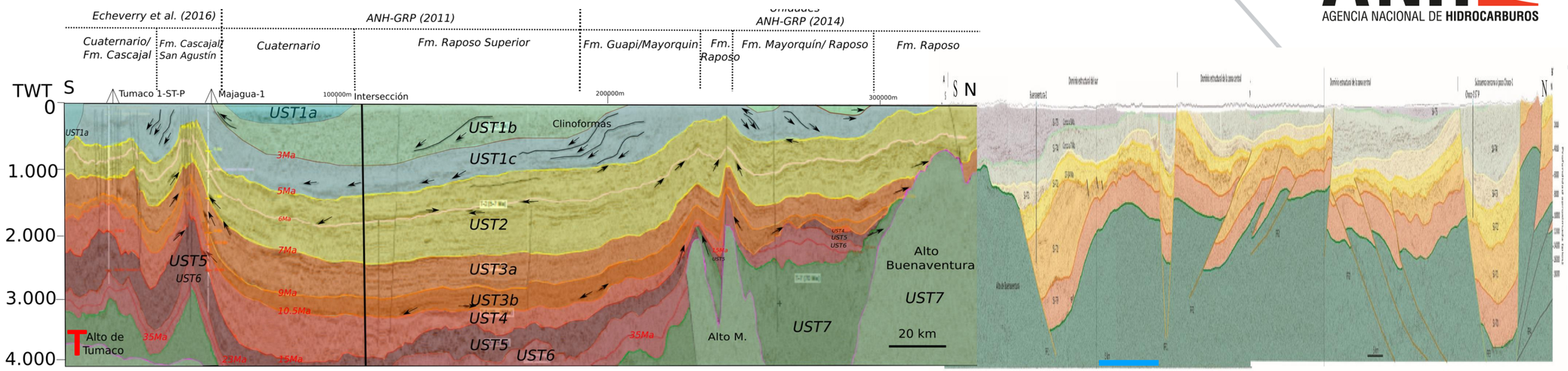
Zapata et al. (2019)

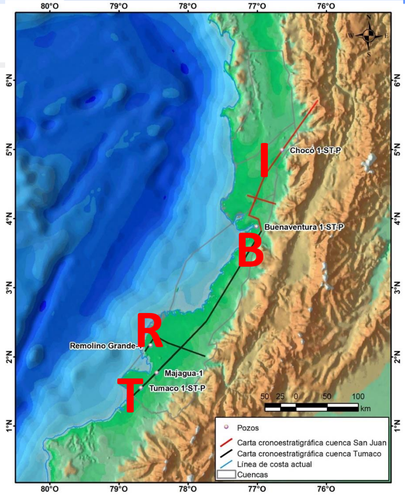


- Paleogene plutonic rocks
- Quebradagrande Complex
- Cauca Ophiolithic Complex
- Late Cretaceous plutonic rocks
- Upper Abejorral M.
- Lower Abejorral M.
- Arquia Complex
- Oceanic Caribbean plateau
- Jurassic igneous rocks
- Continental basement



Tumaco-Piñon block





Tumaco onshore basin **B= Buenaventura and M highs** **San Juan onshore basin**

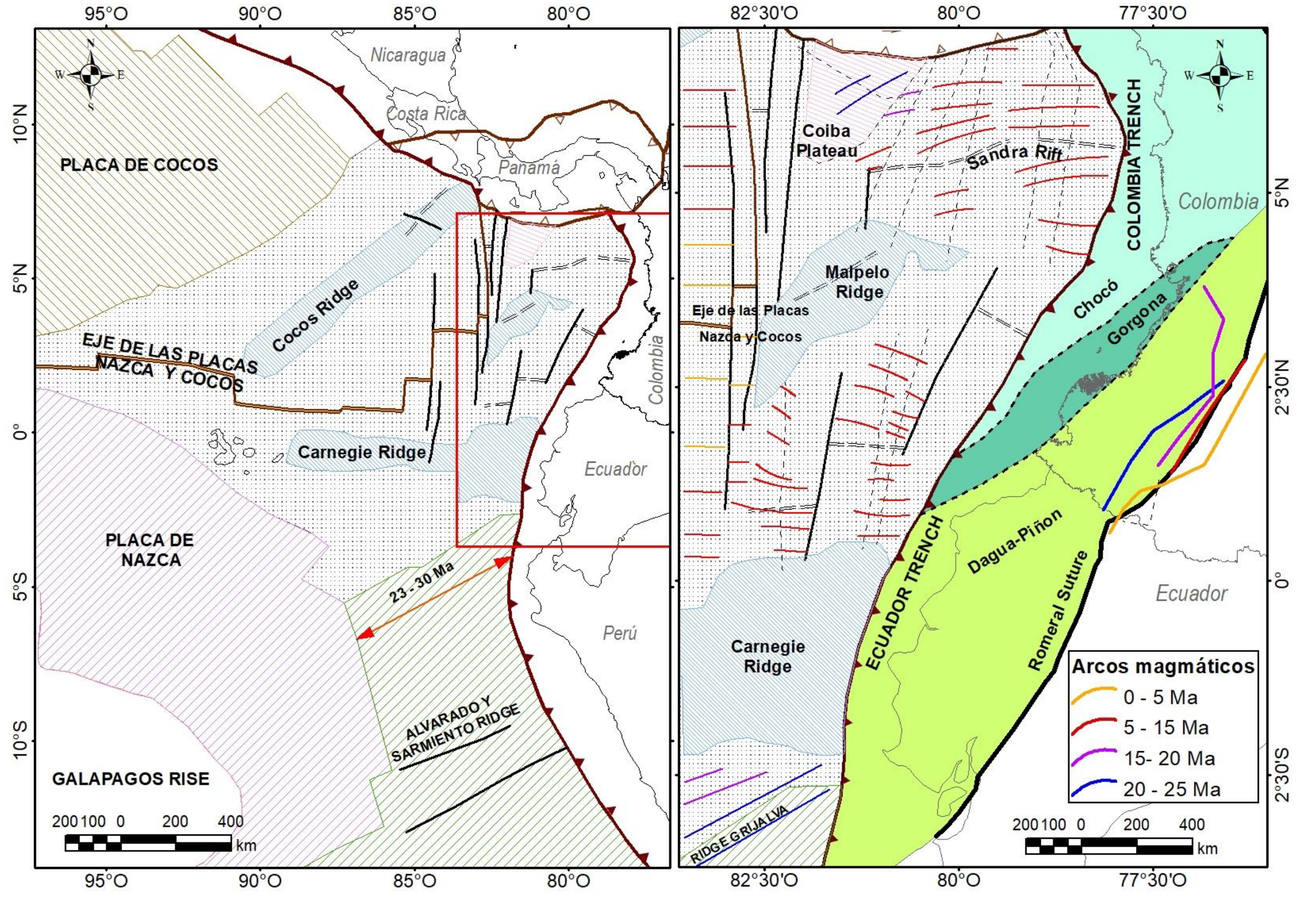
MAJOR CONCLUSIONS OF THE CHRONOSTRATIGRAPHY AND PALEOGEOGRAPHY

1. The Buenaventura and M highs separates the Neogene stratigraphy and structural styles of the Tumaco and San Juan basins.
2. Several intraplate highs (T= Tumaco, R= Remolinogrande, B=Buenaventura; I=Isthmina) played a control in the Neogene evolution of onshore forearc basins.
3. Neogene strata of the Tumaco and San Juan onshore basins record a shallowing trend from deep marine to high-energy marginal environments, constrained by seismic, stratigraphy and bistratigraphic data.
4. Upper Cretaceous to Paleogene strata, which include possible source rocks in both basins, are poorly studied and require data to constrain the palinspastic restoration of the Pacific margin

3. Structural frame of the San Juan and Tumaco basins

By Andreas Kammer, PhD

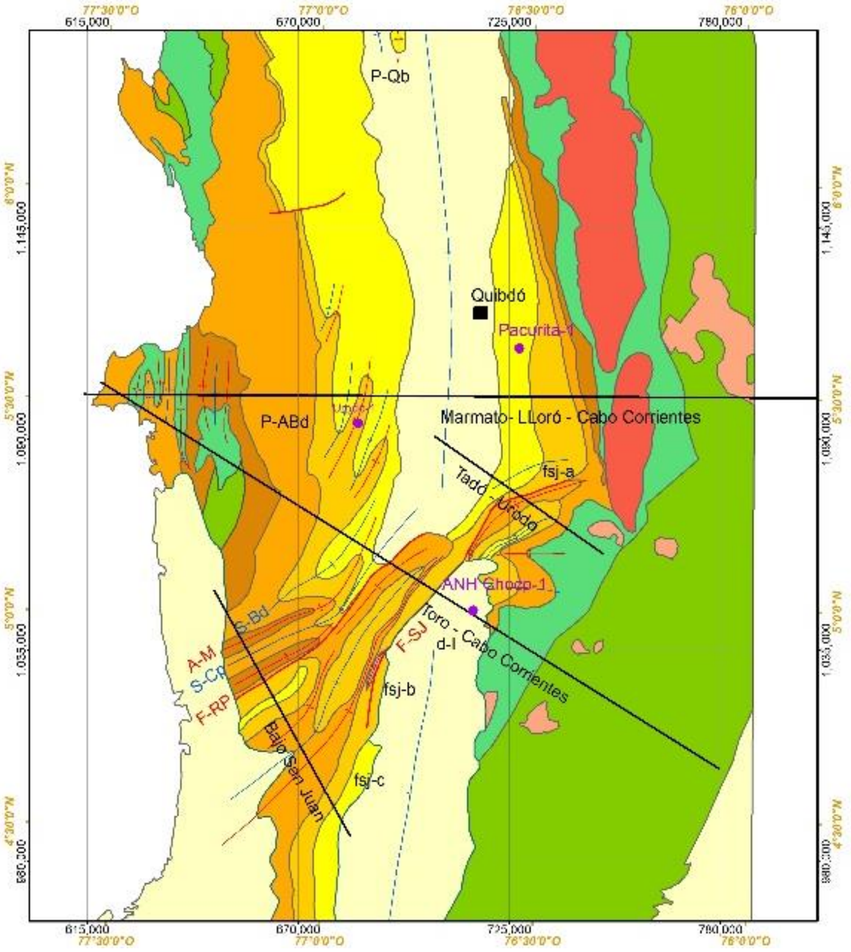
Tectonic blocks and arc elements



Tectonic blocks and arcs (Lonsdale, 2005; Cedial, 2003)

- The ***Choco arc*** contains the Atrato-Chucunaque basin.
- The ***Gorgona arc*** is a transverse micro-block bordered by the Istmina-Condoto High on its northern margin and is separated toward the southern Dagua Piñón terrane by the Garrapatas fault.
- The ***Dagua Piñón terrane*** contains the Tumaco basin.

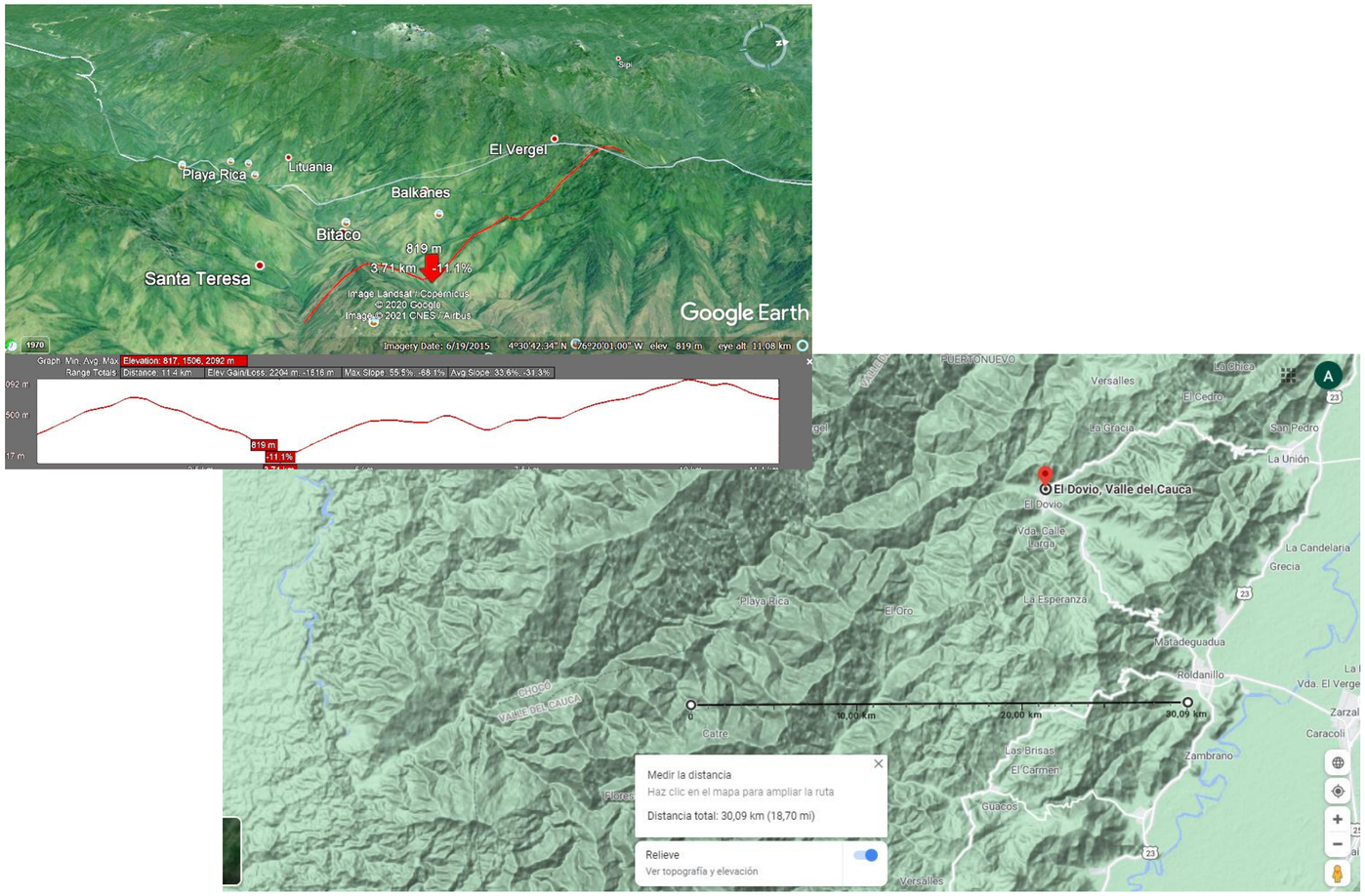
Setting of the Atrato and San Juan basins



Simplified geology, compiled from the Geological Atlas 1:500.000

- ***Atrato Basin:*** enclosed between Mandé arc and Baudó range: CLIP-basement on both sides is overlain by Paleogene platform sediments. Paleogene to Neogene sedimentary fill.
- ***Istmina-Condoto high:*** complexly folded and fault-bounded ridge.
- ***Garrapatas fault:*** distinct lineament without a correlatable geologic expression.

Setting of the Atrato and San Juan basins



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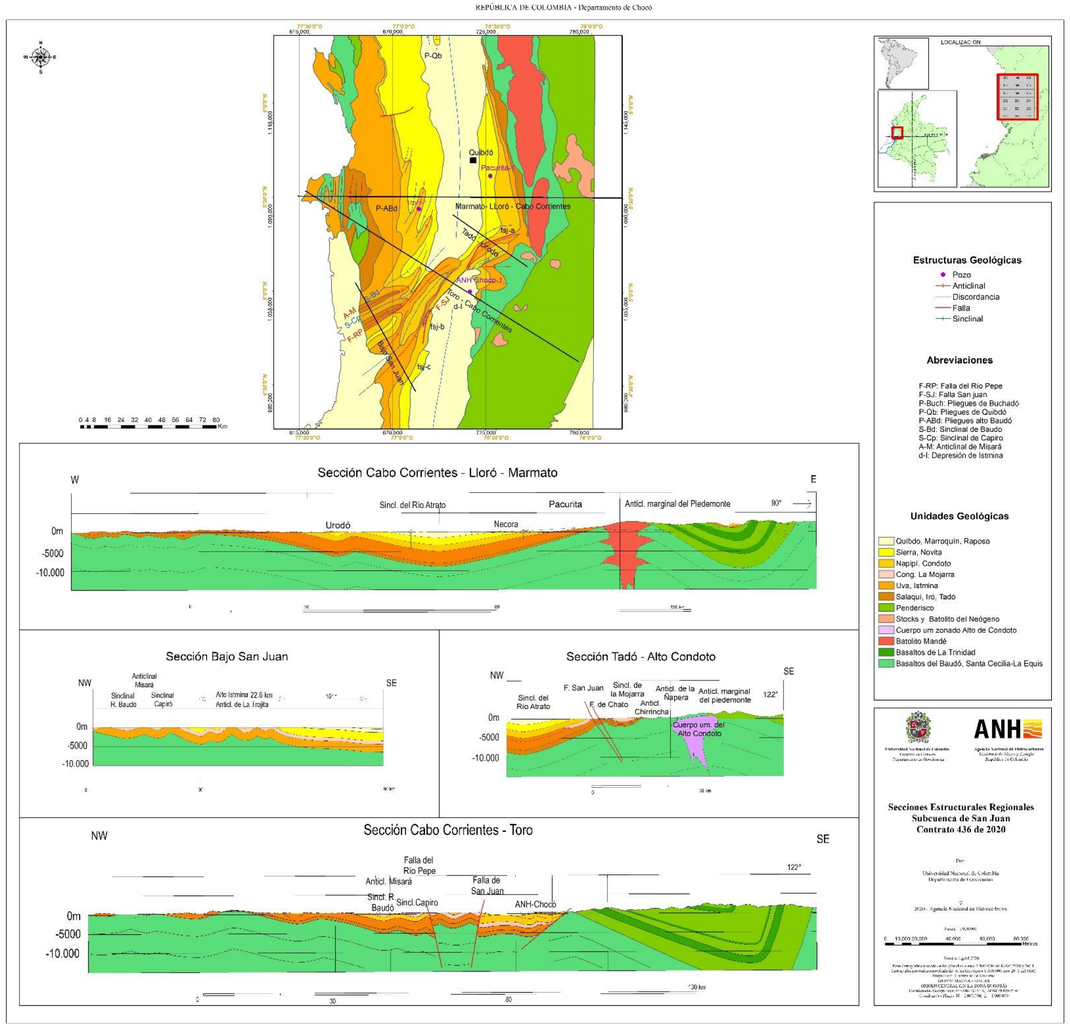
Simplified geology, compiled from the Geological Atlas 1:500.000

COLOMBIA ROUND 2021

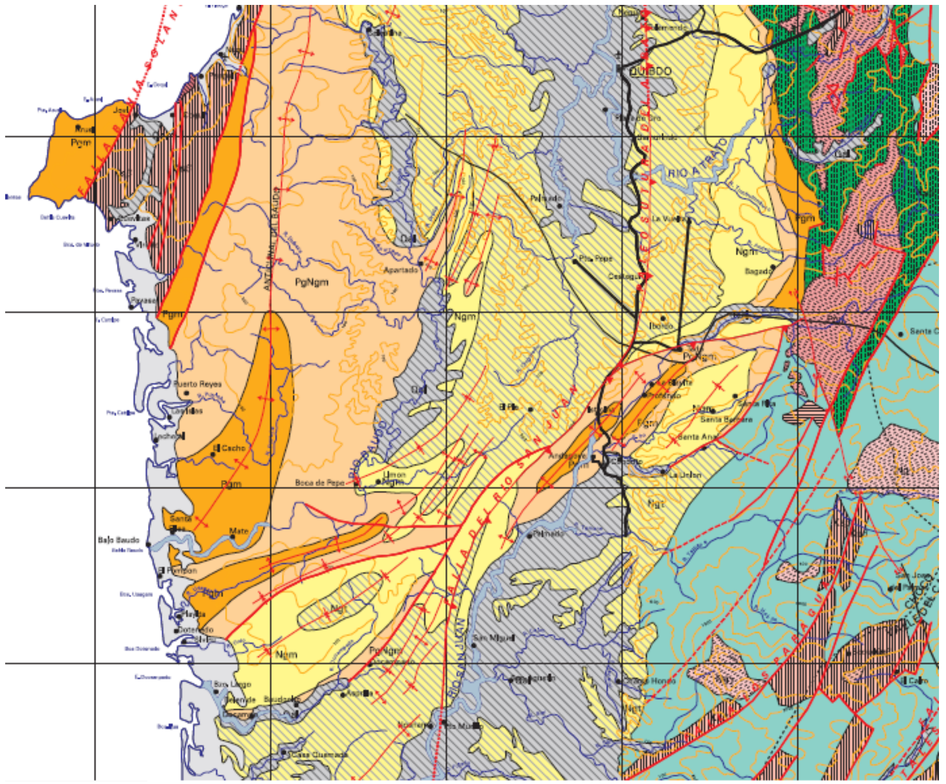
Structural elements



Simplified geology and regional transverse sections

- ***Western Cordillera:*** Folded CLIP-basement; contains syncline with siliciclastic (post-accretionary) cover (Campanian to Maastricht.)
- ***Mandé arc:*** CLIP basement intruded by Mandé batholith
- ***Cenozoic Atrato and San Juan basins:*** symmetric or partially eroded and faulted (eastern flank of San Juan basin)
- ***Baudó Range:*** forms ample western flank of Atrato basin
- ***Pliocene to recent sediments*** (above angular unconformity)

Map-scale structures of Atrato basin

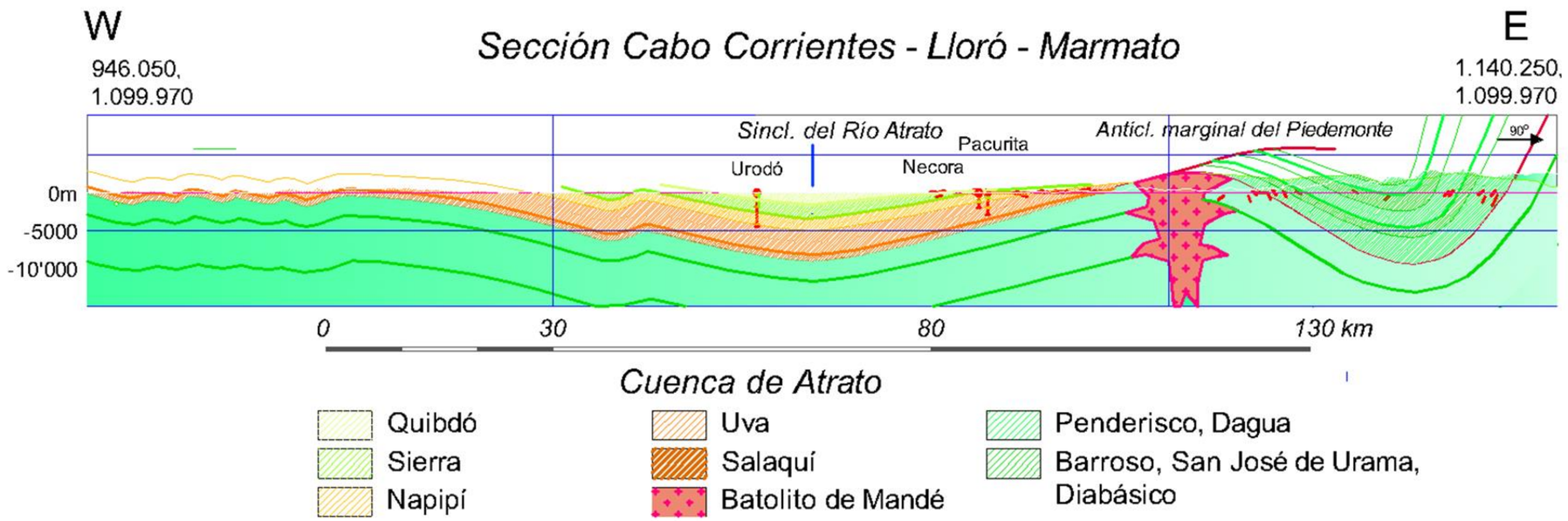


- ***Folded sedimentary cover of Lower Baudó region:***

  Folds tend to turn into parallelism with those of the Istmina-Condoto high

Simplified geologic and relief map (Google Earth)

Regional E-W transverse section: Baudó range - Atrato basin - Mandé Arc - WC

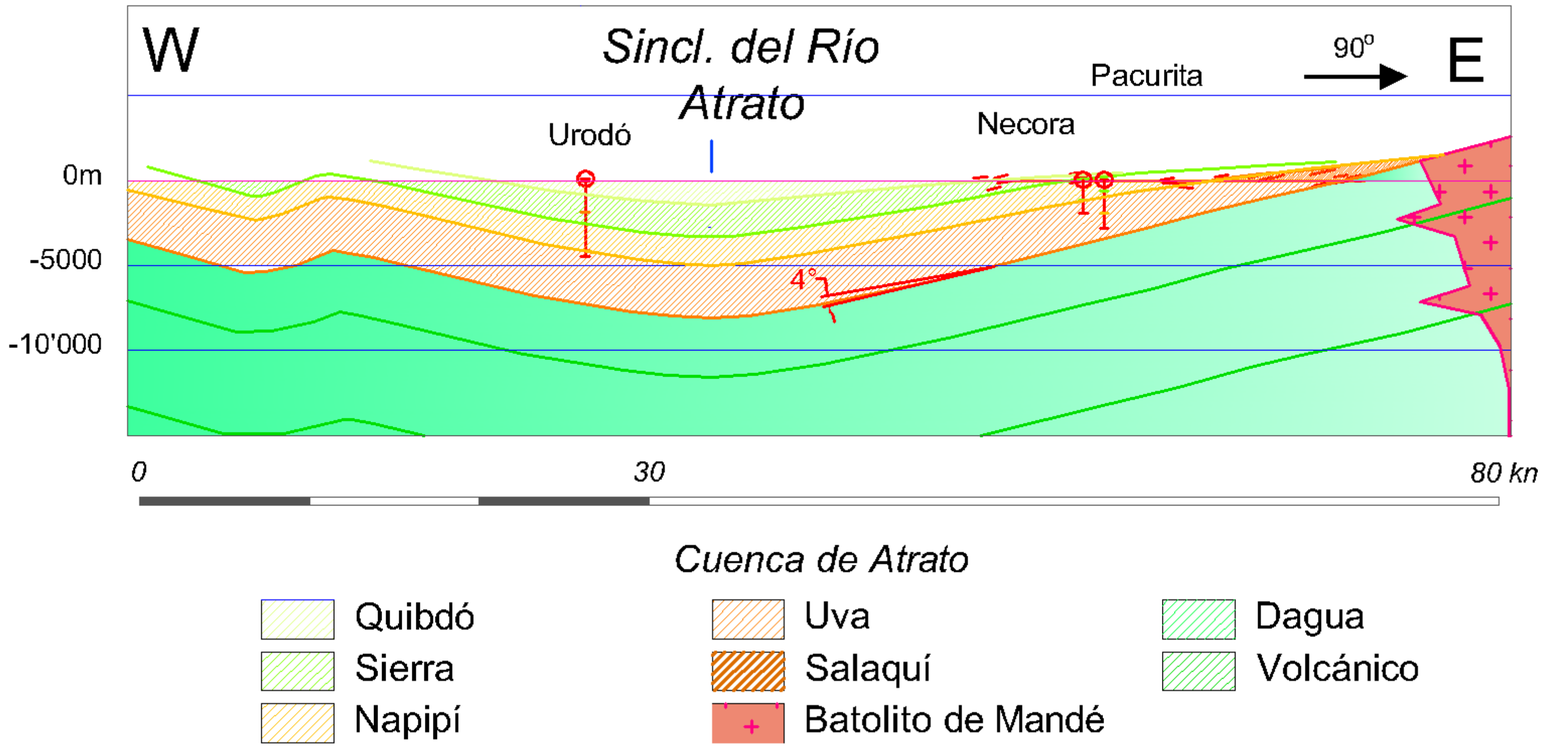


Elements:

- *Infolded Late Cretaceous cover*
- *Mandé arc: Mandé batholith intrudes a Late Cretaceous to Paleogene volcanic effusive sequence*
- *Open transverse fold in eastern flank of Baudó Range*
- *Tighter folds in hinge area of Baudó Range*

Transverse section constructed from surface data

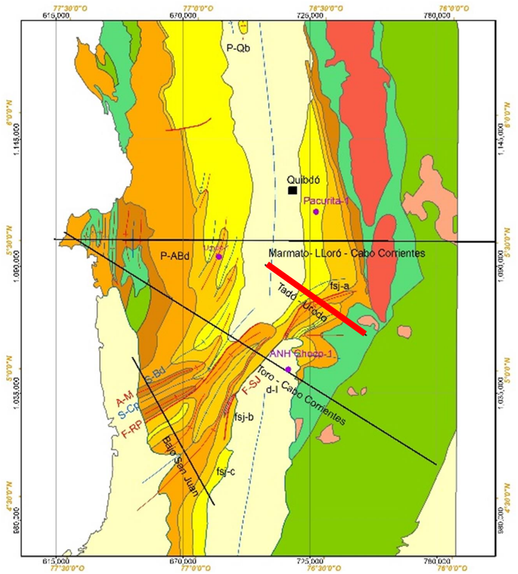
Regional E-W transverse section: Atrato basin (close-up)

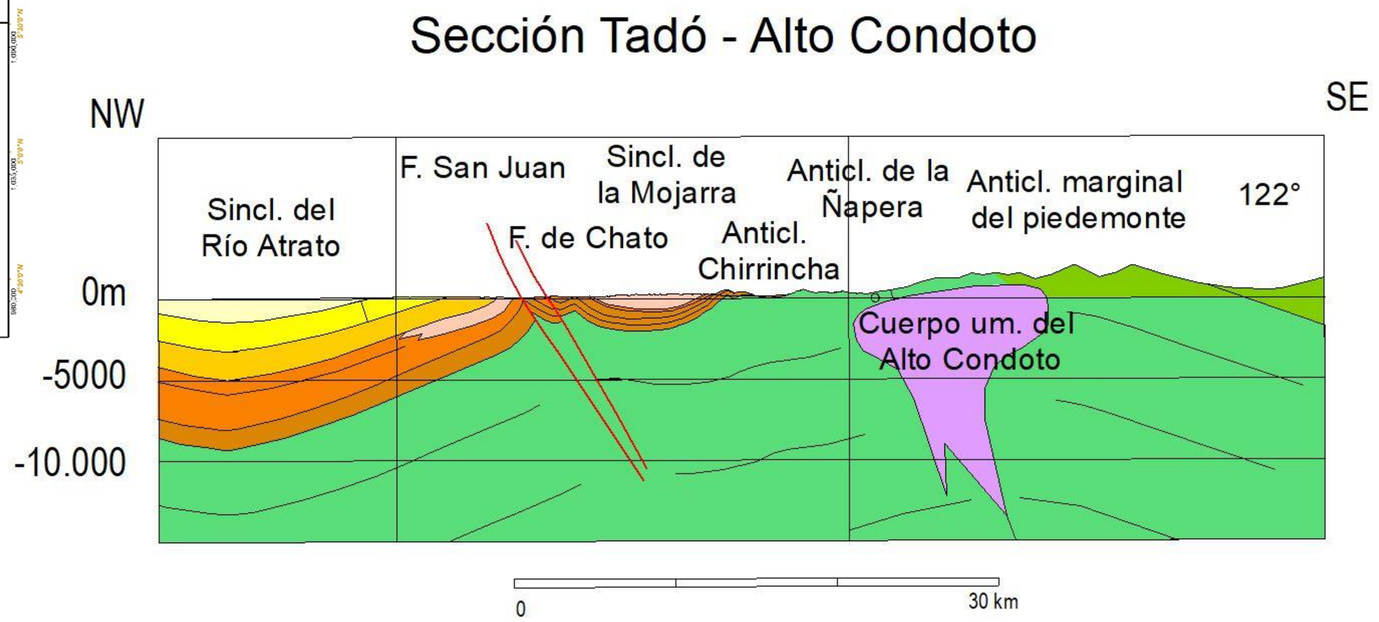


Basin-wide geometry: formations correlate well between the two flanks

Simplified geologic and relief map (Google Earth)

Transverse section of the eastern transverse range



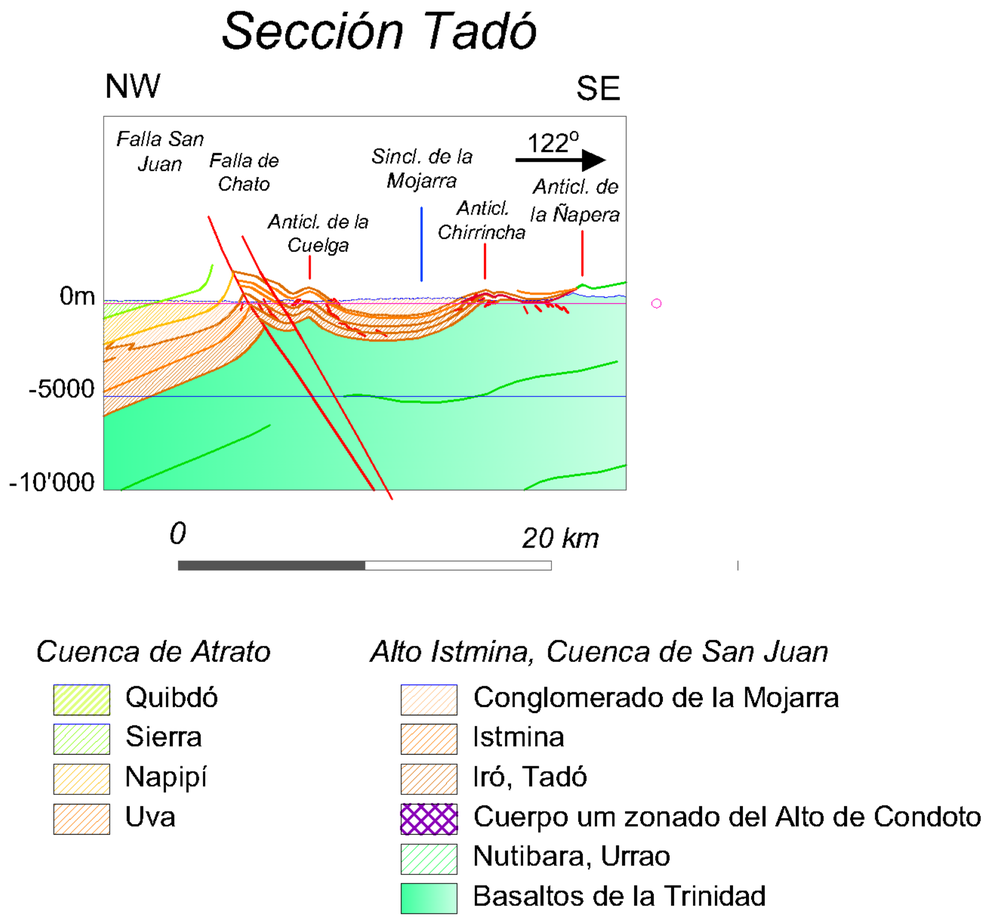


Elements:

- *Marginal antiform cored by the ultramafic Condoto complex*
- *Synformal crest of the Istmina-Condoto high*

Transverse section constructed from surface data

Transverse section of the eastern transverse range (close-up)

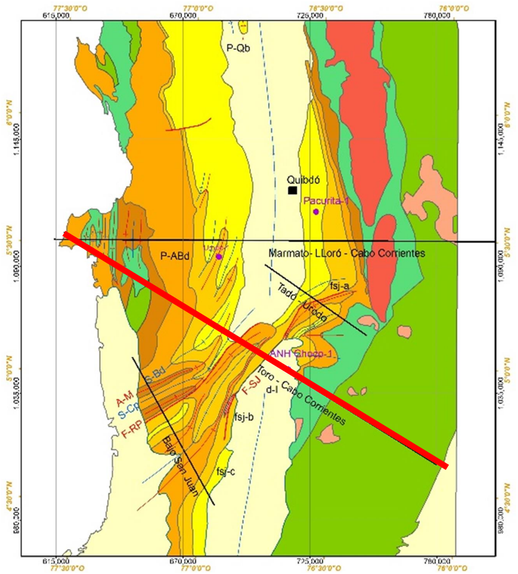


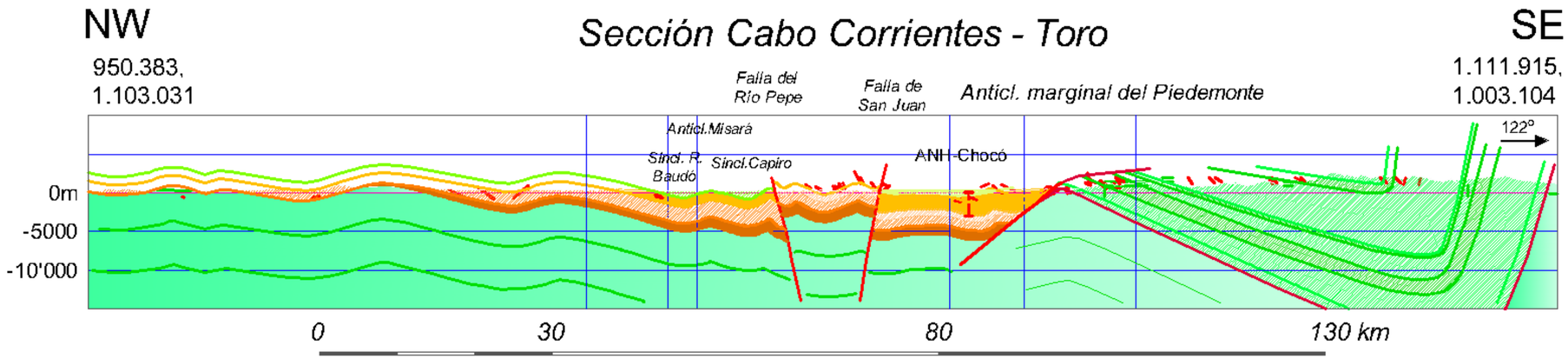
Elements:

- *Axial syncline is bordered by rim synclines and anticlines*
- *Conglomeratic fill of axial syncline (Early Miocene La Mojarra Conglomerate)*

Close-up of transverse section (constructed from surface data)

Transverse section of the central transverse range and the WC





Cuenca de Atrato

- Quibdó
- Sierra
- Napipí
- Uva
- Salaquí
- Baudó

Alto Istmina, Cuenca de San Juan

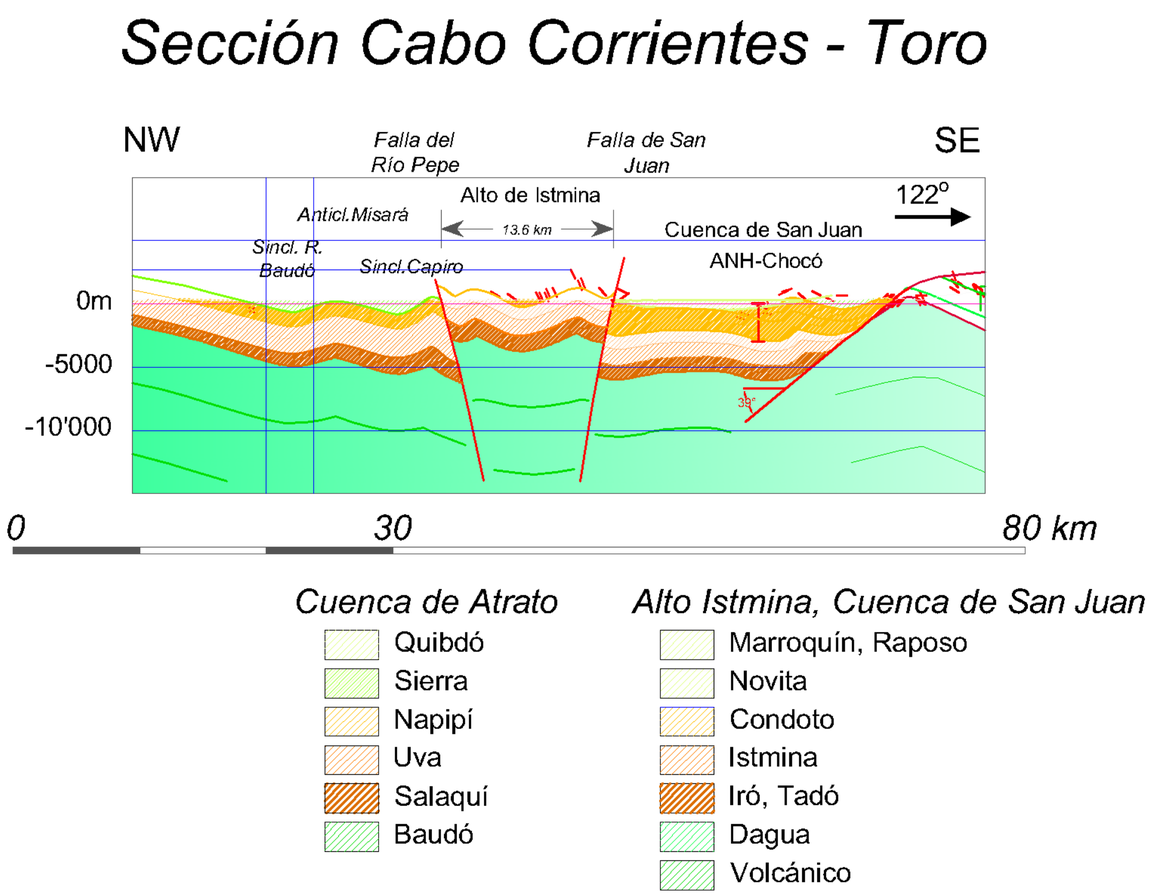
- Marroquín, Raposo
- Novita
- Condoto
- Congl. La Mojarra
- Istmina
- Iró, Tadó
- Dagua
- Diabásico

Elements:

- *Istmina-Condoto high is faulted*
- *Synformal crest*

Transverse section constructed from surface data

Transverse section of the eastern transverse range (close-up)

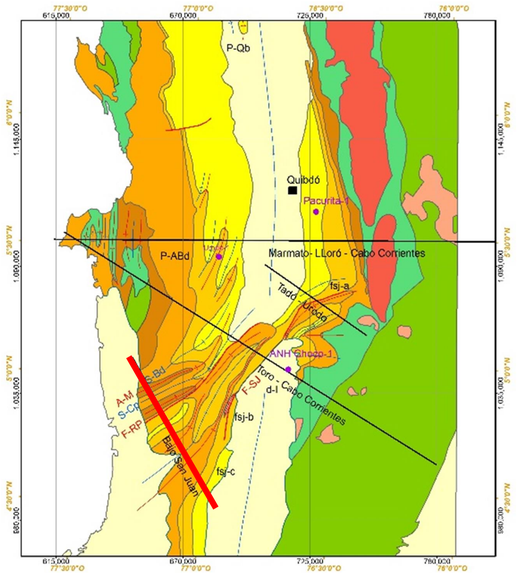


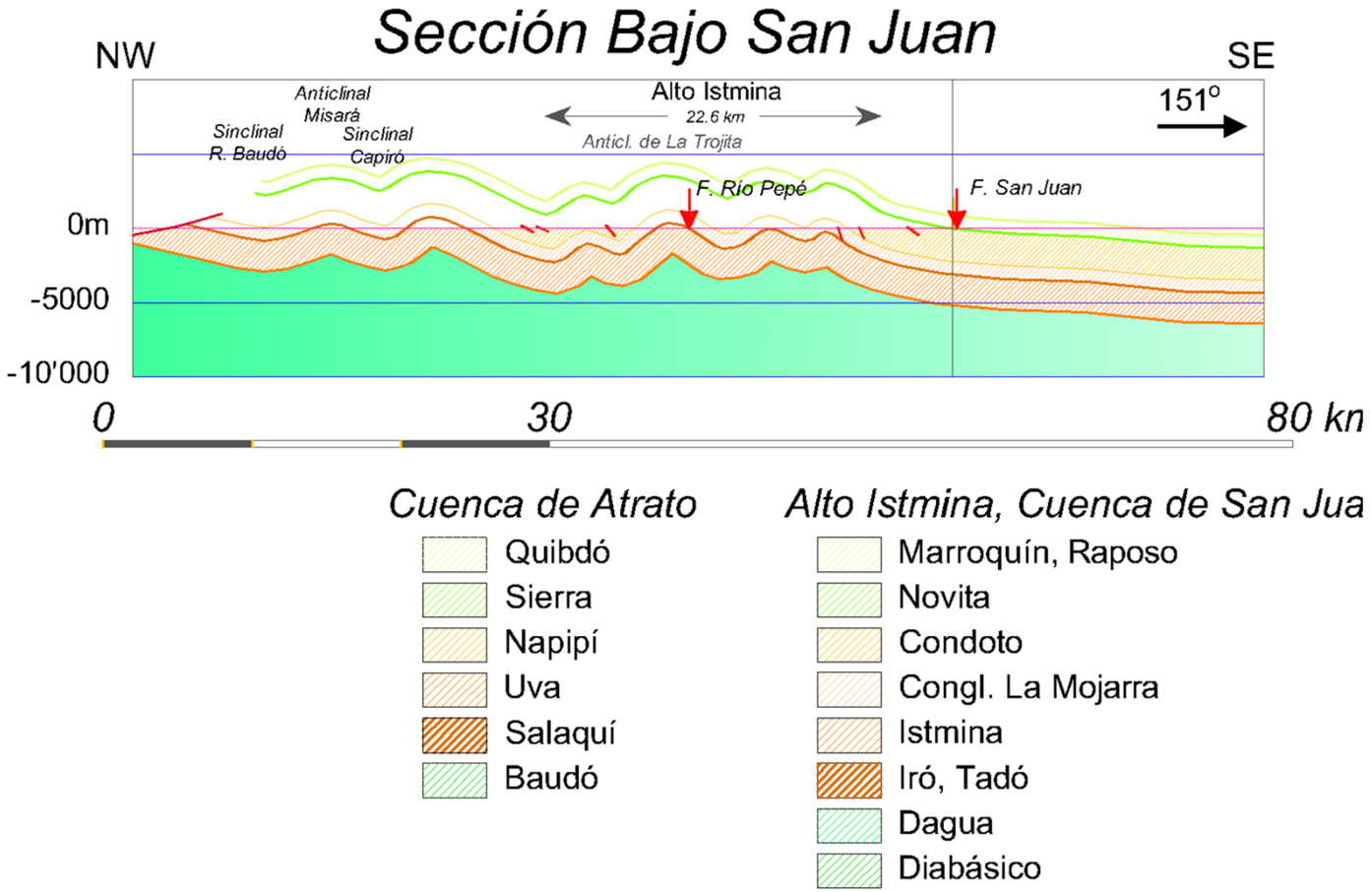
Elements:

- *Contractional horst.*
- *Conglomeratic fill of axial syncline (Early Miocene La Mojarra Conglomerate).*
- *Onlap or faulted contact relations toward the eastern flank of the San Juan basin?*

Close-up of transverse section (constructed from surface data)

Transverse section of the southwestern segment of the transverse range



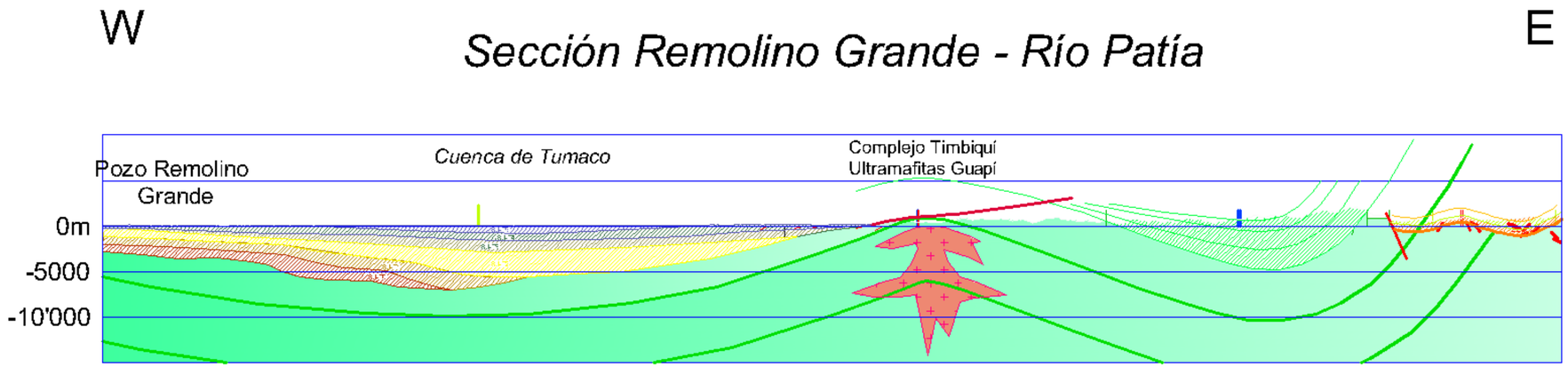


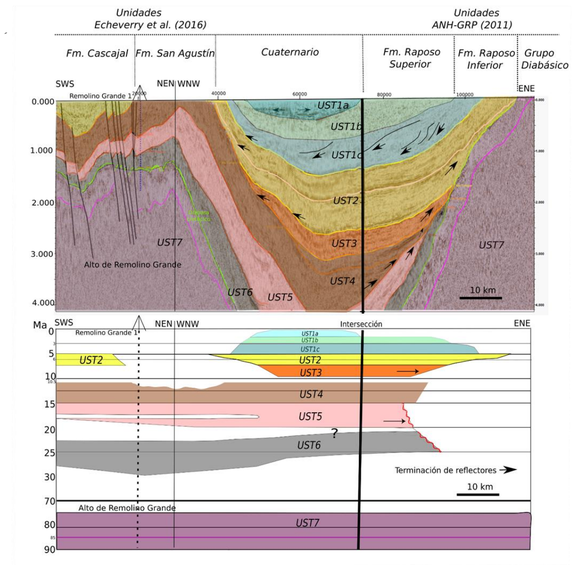
Elements:

- *Border faults of the Istmina-Condota high are absent.*
- *Folding of the Istmina-Condoto is tight (low wavelengths).*

Transverse section constructed from surface data

Transverse section of the Tumaco Basin



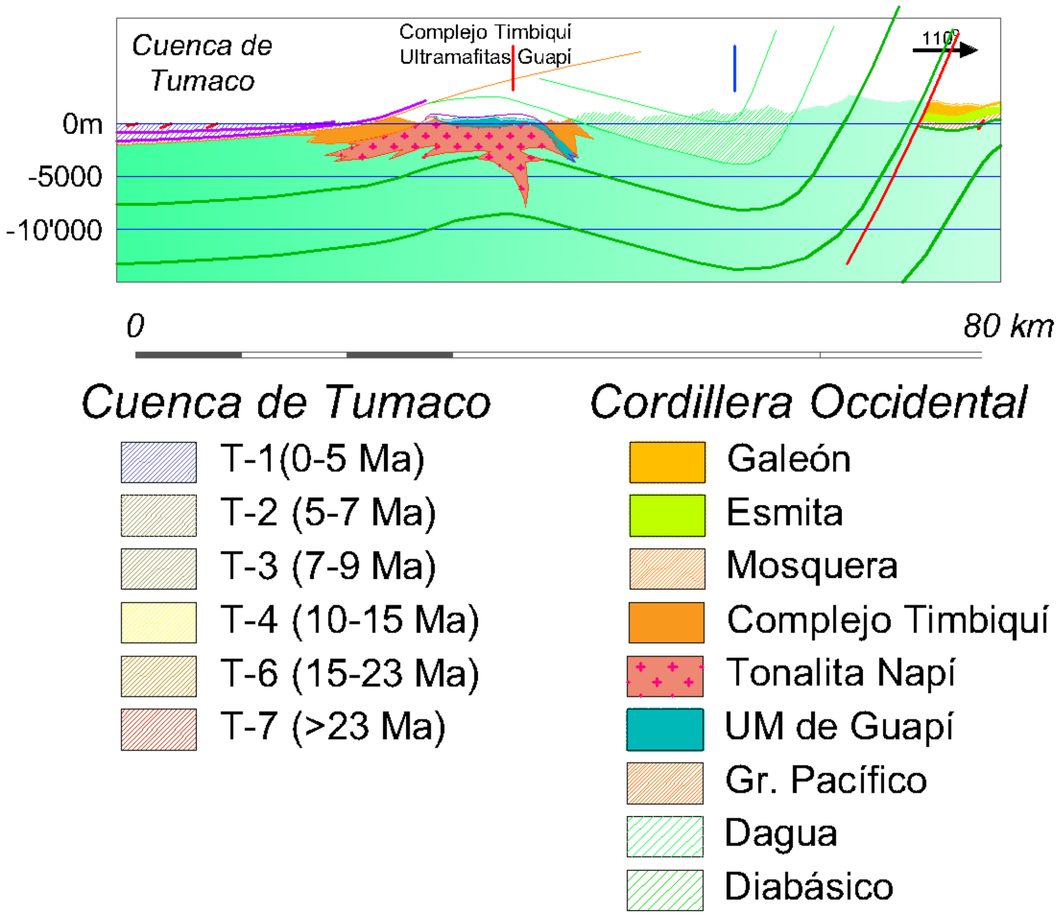


Transverse section constructed from surface data

Elements:

- *Asymmetric basin fill*
- *Marginal western anticline: the Timbiquí complex is a southern continuation of the Mandé arc?*
- *Central syncline of the WC with Campanian to Maastrichtian fill*

Transverse section of the Tumaco Basin: the WC



Transverse section constructed from surface data

Elements:

- *Onlap relations of Neogene sediments*
- *Marginal western anticline: the ultramafic Guapí complex forms a lid of the underlying Napí stock; the Timbiquí complex forms a subvolcanic-volcanic complex below Paleogene sediments of the Pacific group.*

Questions instead of conclusions

- Are the Mandé arc and the central syncline of the WC continuous and correlatable elements? Do they belong to a uniform “western cordilleran” terrane? What is the significance of the Garrapatas fault?

- Provided the Chocó-Panama arc and the southern micro-blocks belong to a closely associated terrane assemblage, what is the significance of the transverse Istmina-Condoto range? Did it form by the subduction of an aseismic ridge?

- Did the emplacement and exhumation of the Mandé-Timbiquí arcs interrupt a western continuation of the siliciclastic cover of the WC?

- Was the formation of the marginal basins (Atrato-San Juan-Tumaco) prompted by a crustal-scale buckling?

4. Structural styles and paleogeographic history of the San Juan Basin, Colombia

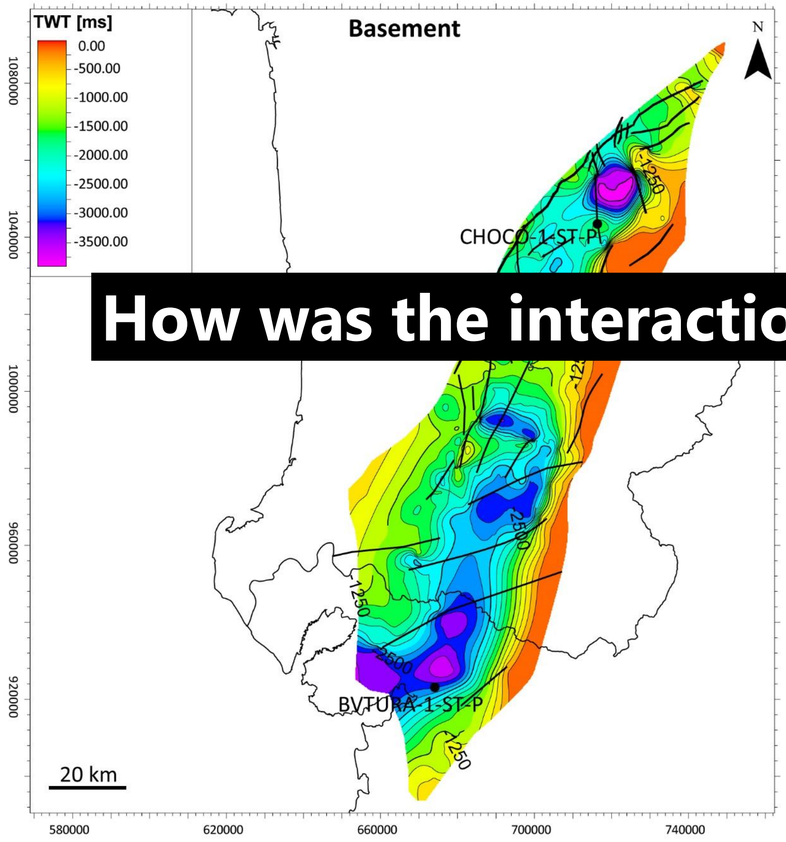
By Dora Marín, PhD

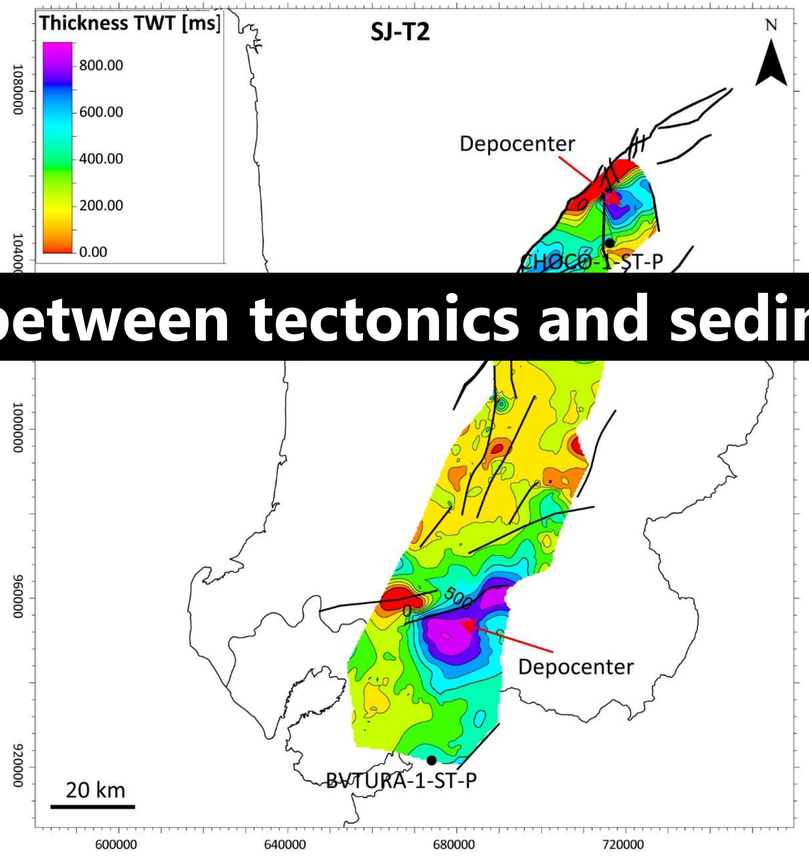
San Juan Basin

Structural elements from Gómez et al. (2019)

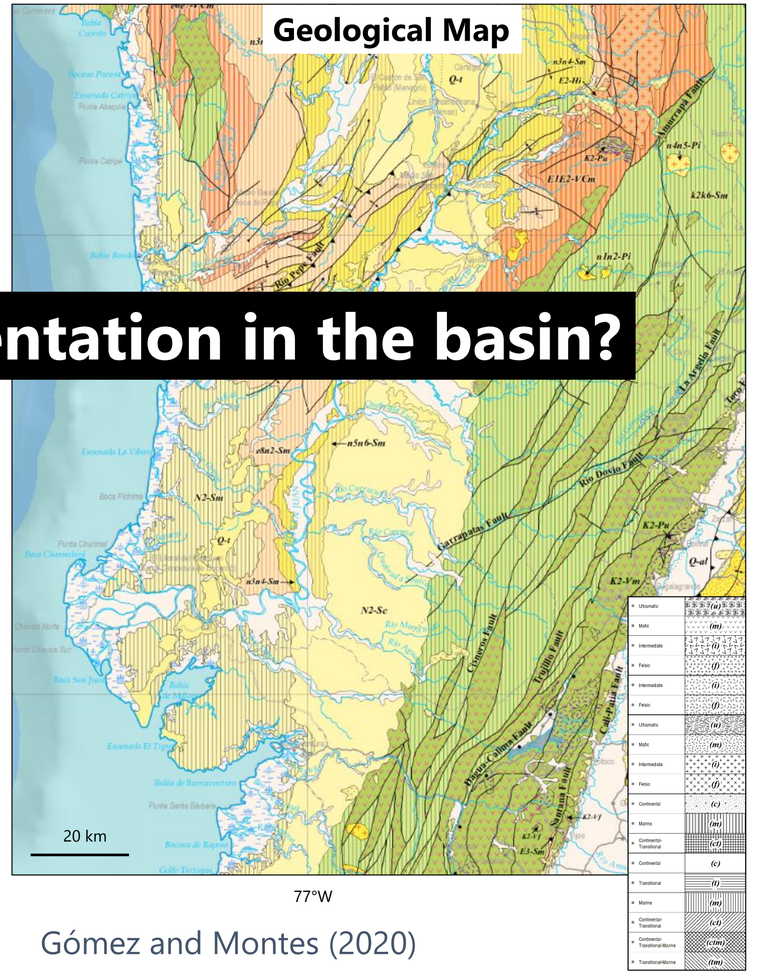
- Forearc basin
- Margin affected by the subduction of the Nazca Plate and different collisions.
- Two tectonic events: middle Miocene and Pliocene (e.g. Duque Caro, 1990; Escalona and Mann, 2011; Montes et al., 2015; Leon et al., 2018).

San Juan Basin





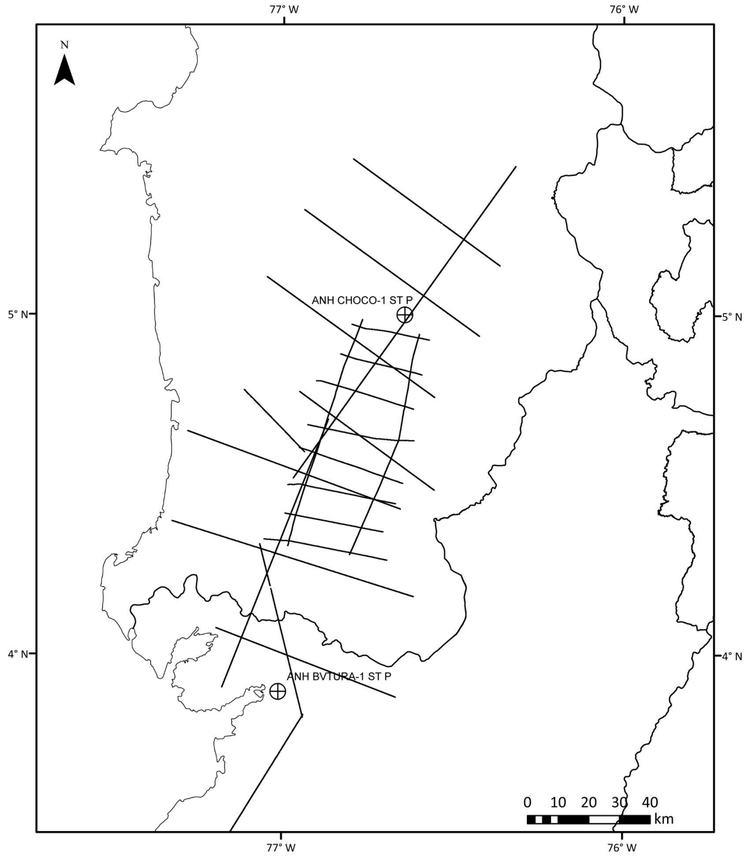
How was the interaction between tectonics and sedimentation in the basin?



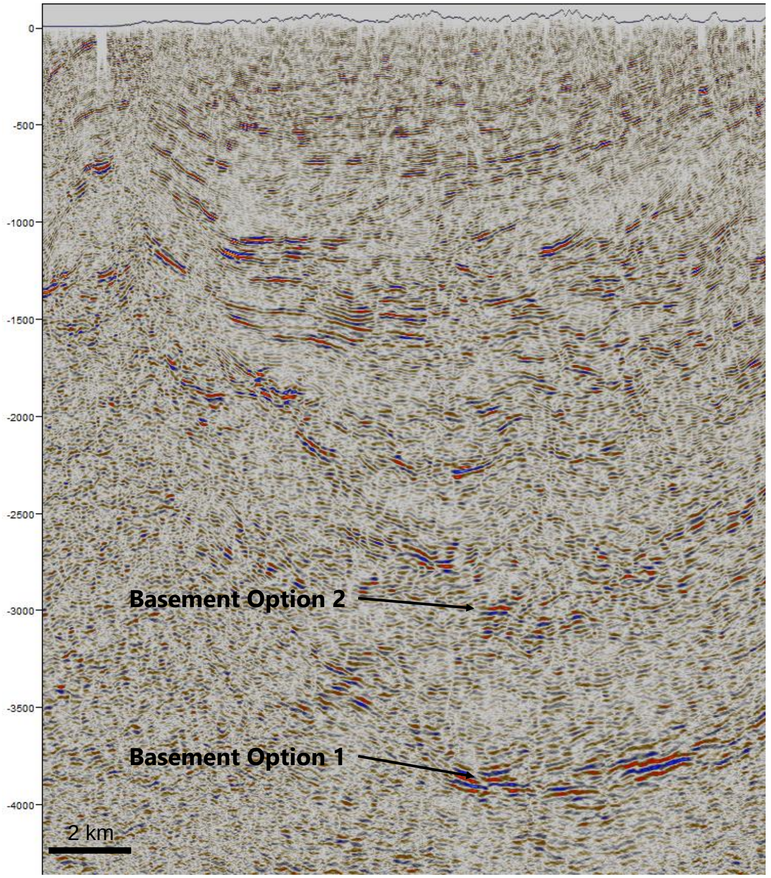
Gómez and Montes (2020)

Dataset and Uncertainty

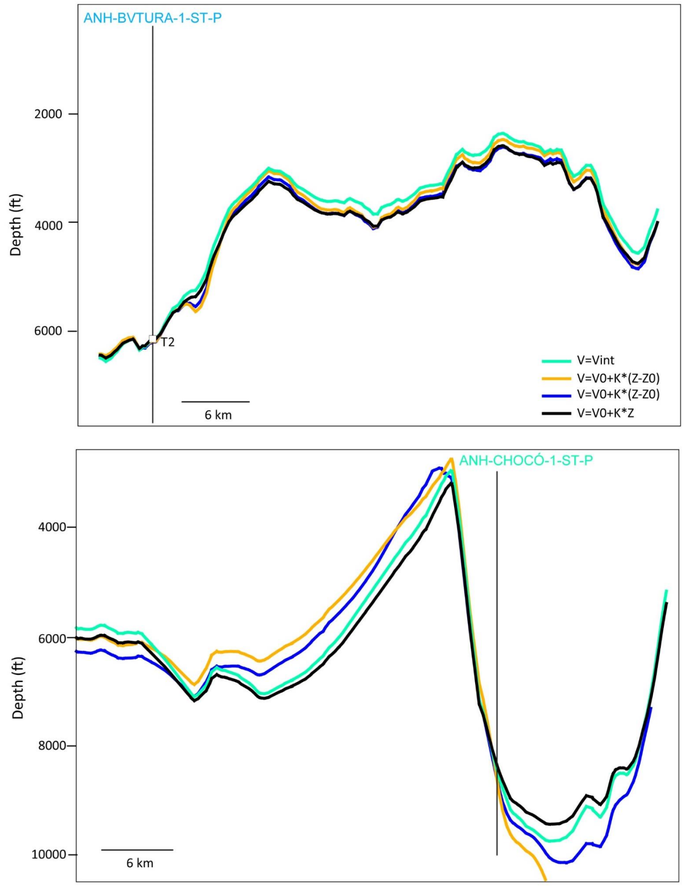
Dataset



Uncertainty in the interpretation



Uncertainty in the T-D conversion



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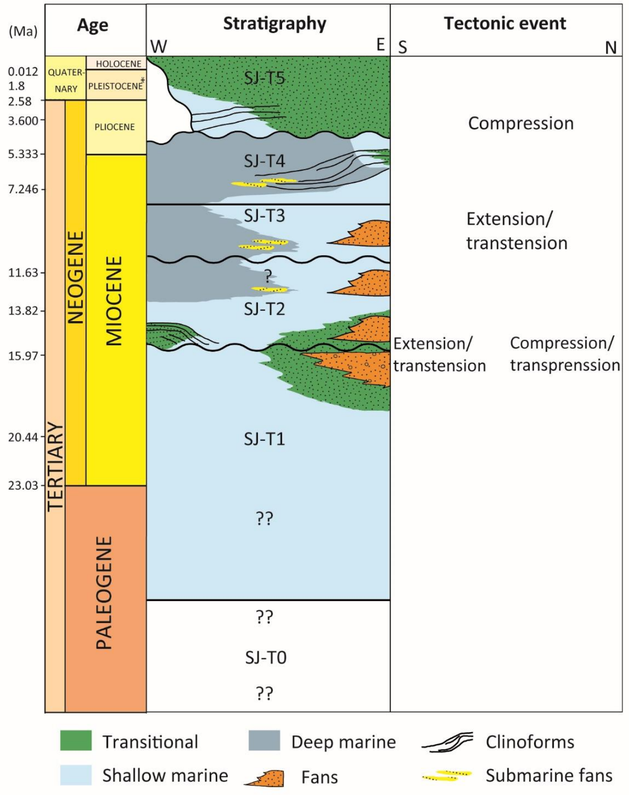
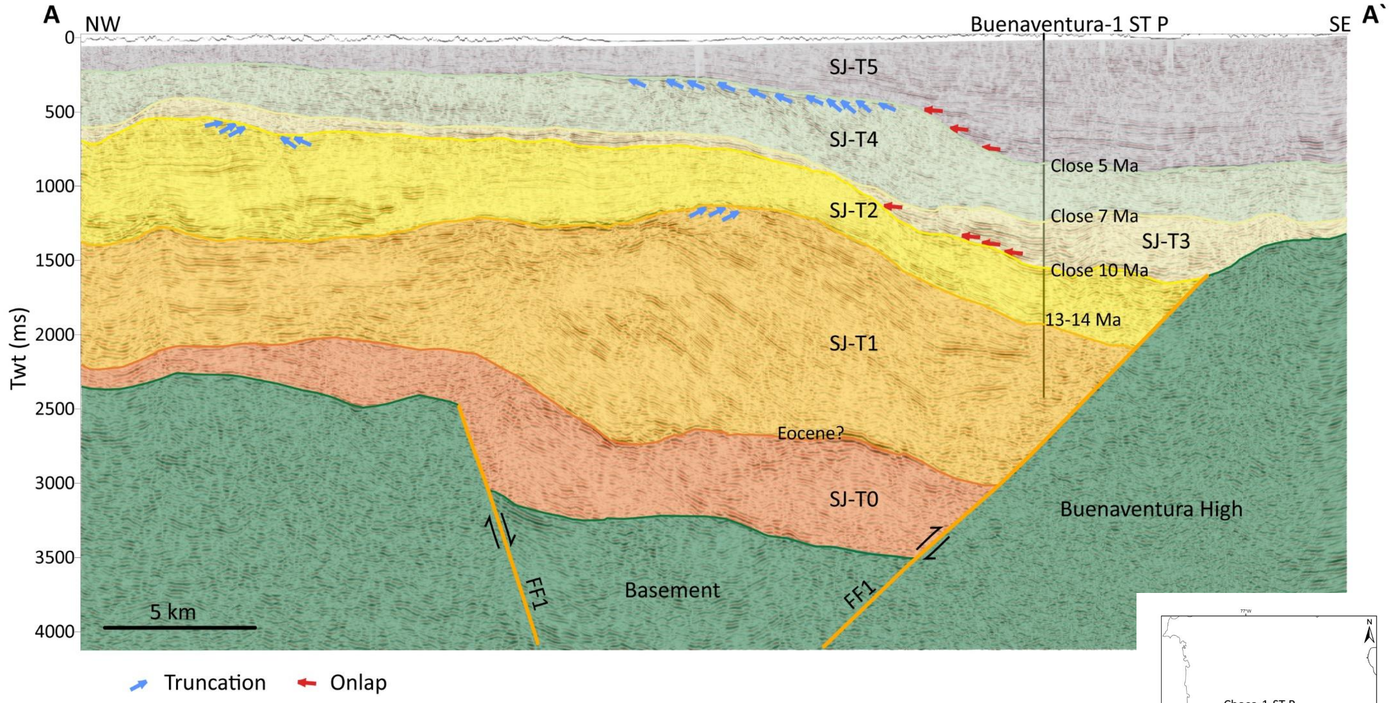
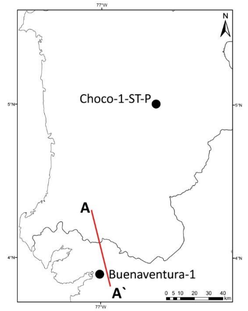
Stratigraphic Framework

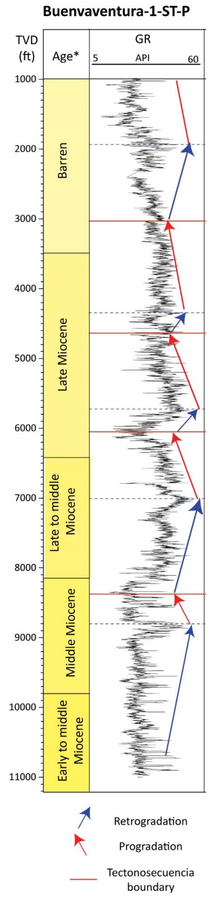
Six sequences were defined using stacking patterns and terminations





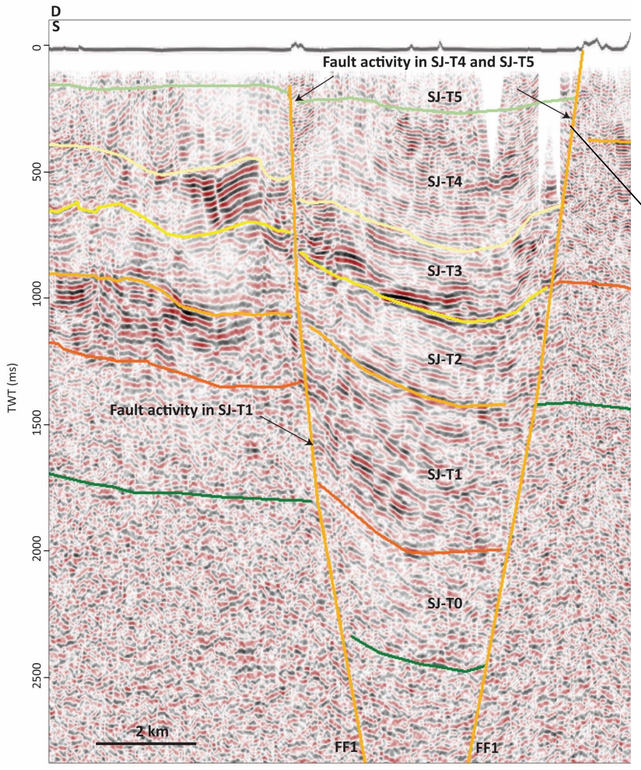
Age from Duque-Herrera et al. (2018)

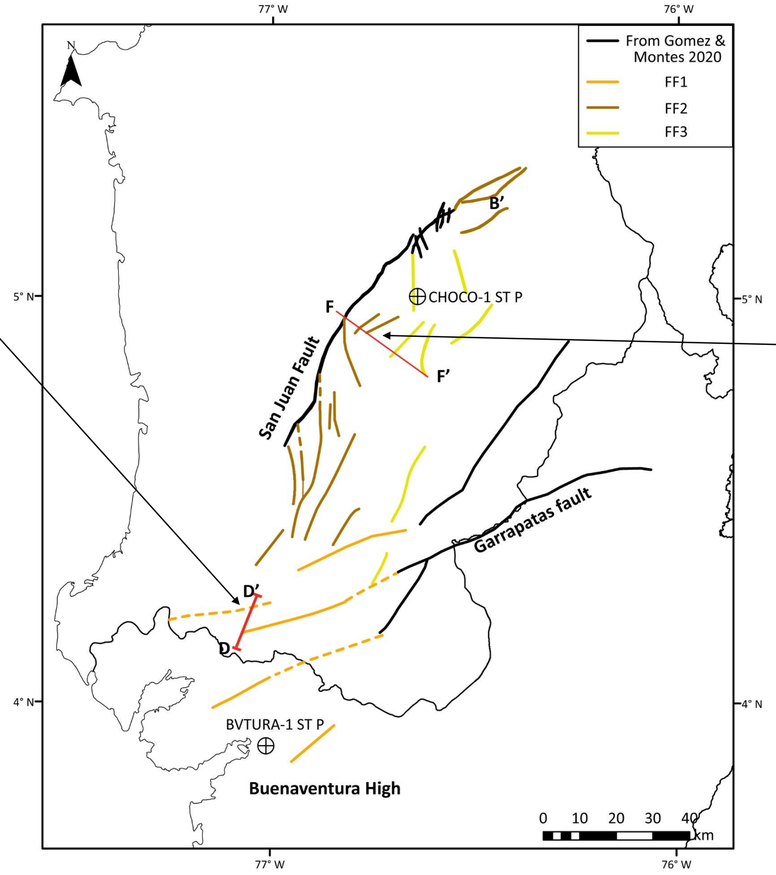




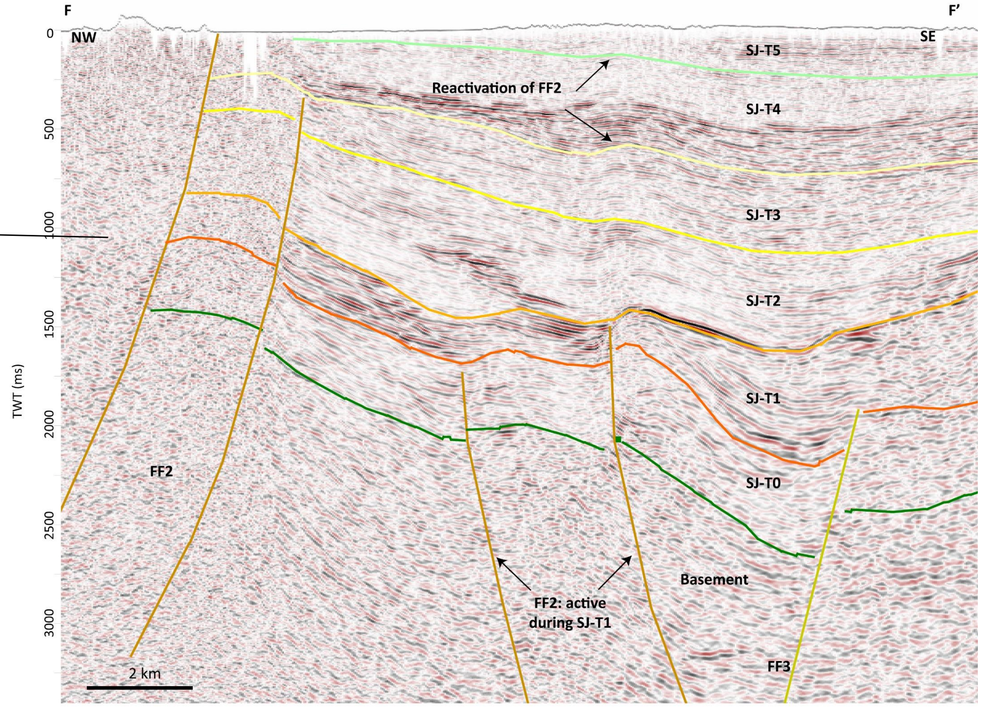
Structural styles in the San Juan Basin

FF1: Faults with normal component

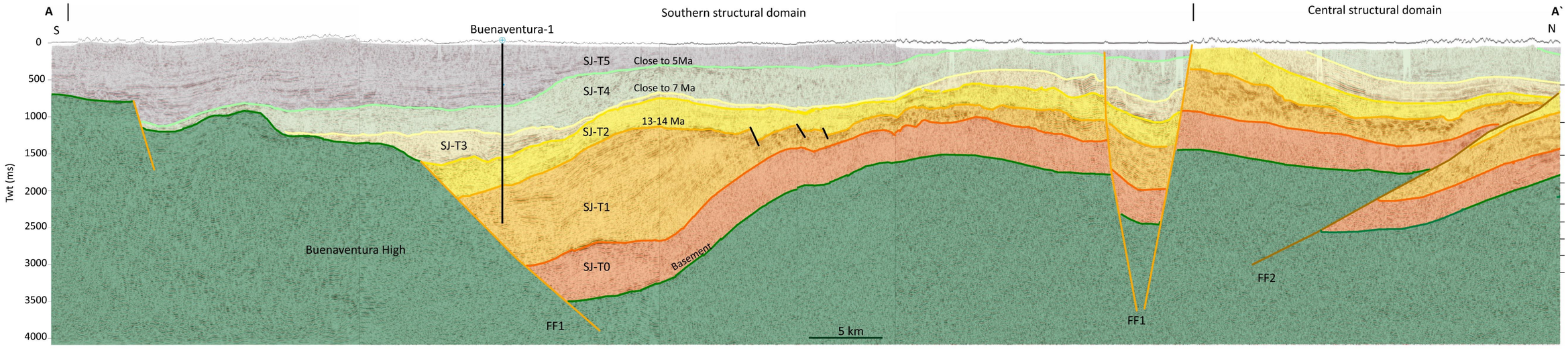


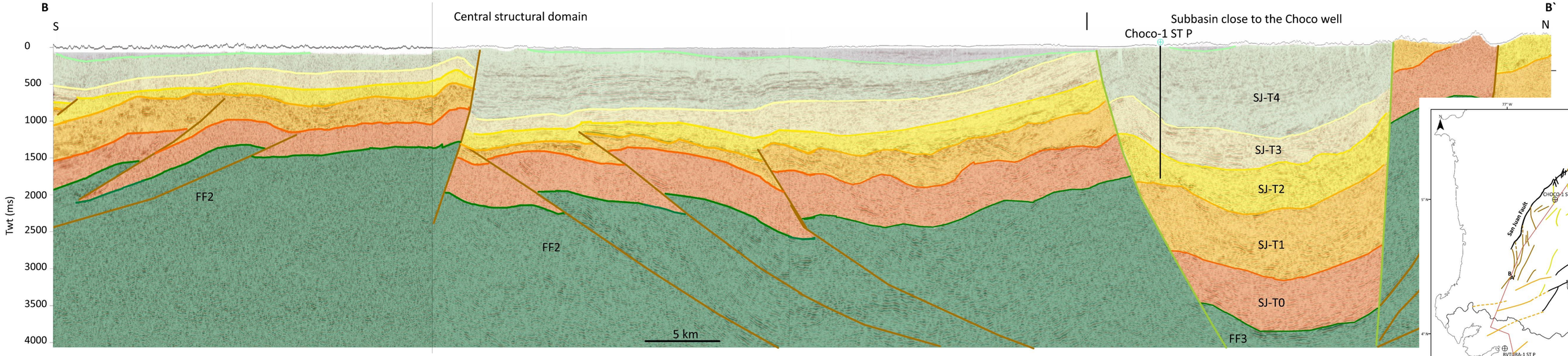


FF2: Reverse faults, active during SJ-T1 and SJ-T5

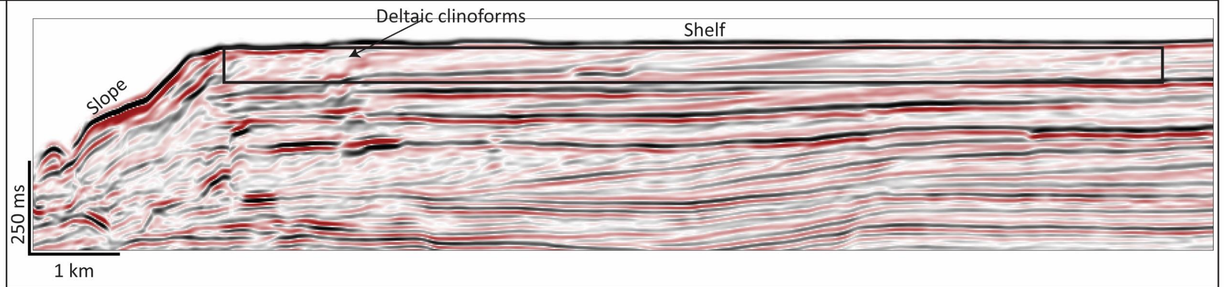
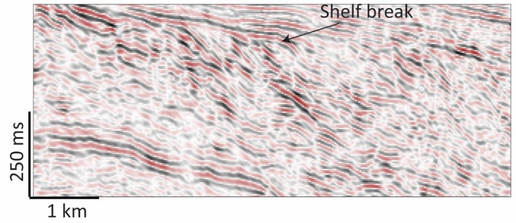
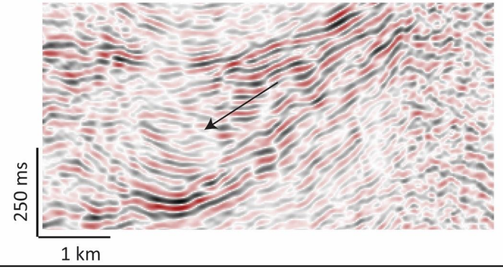
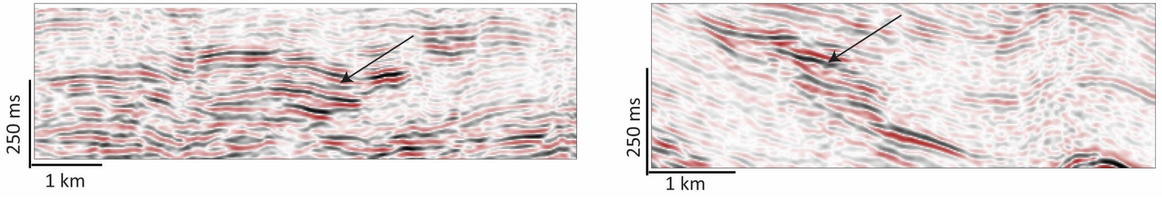


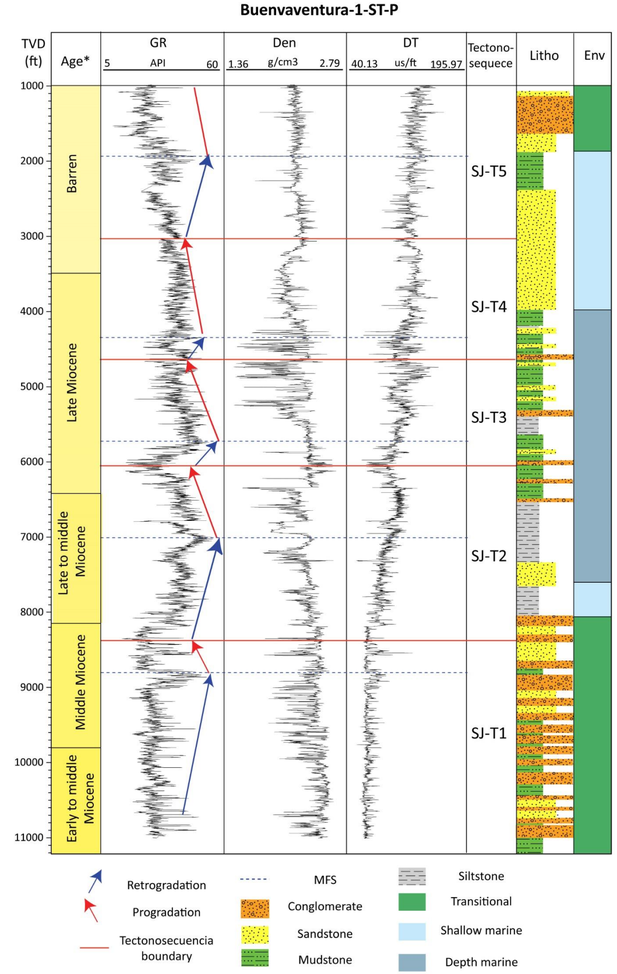
Structural style in the San Juan Basin





Seismic facies and paleoenvironments

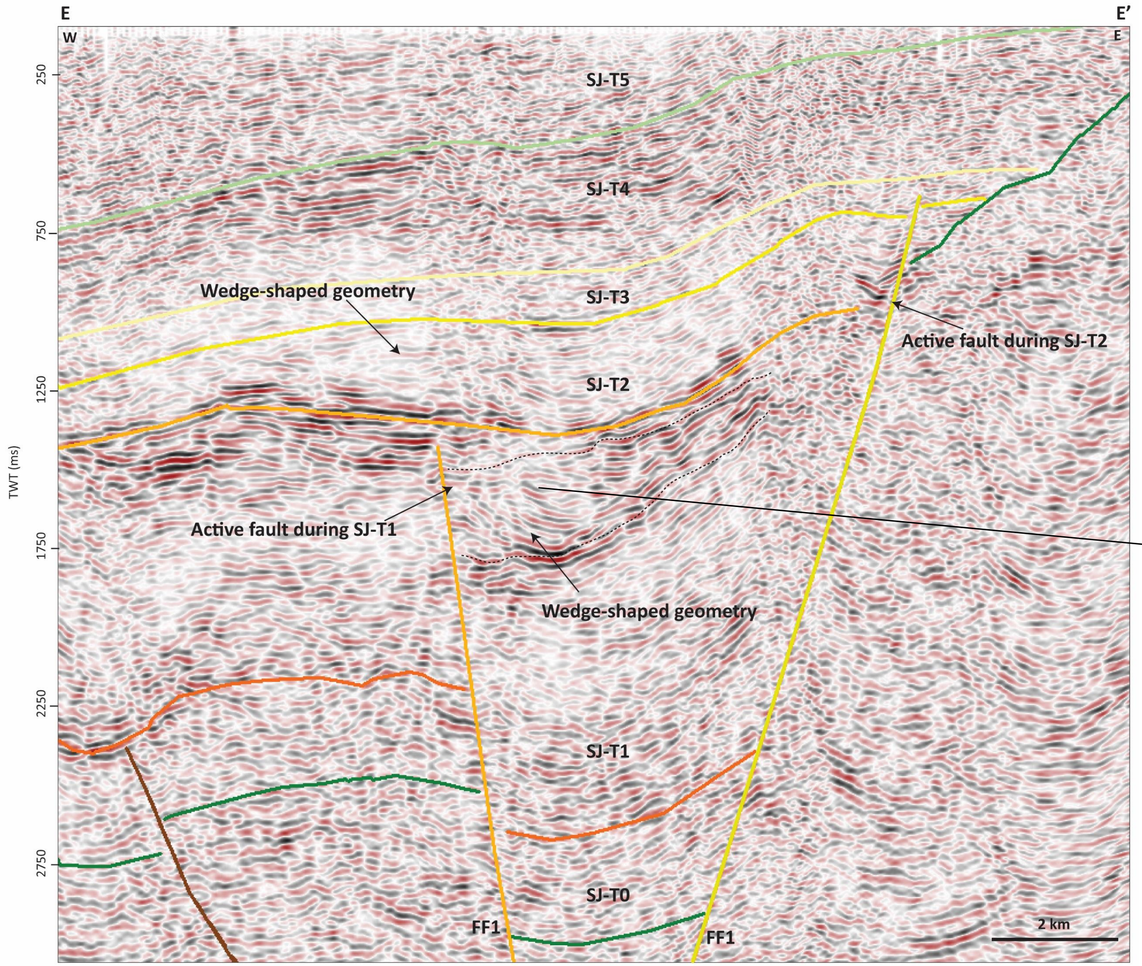
Description	Interpretation	Example
SF3a:Clinoforms with a height of less than 150 m	Deltas/Shorelines	
SF3b: Clinoforms with a height of more than 150 m	Shelf-margin clinoforms Turbidites might be present in bottomsets	
SF4: Wedges located close to a fault or scarp	Structurally controlled fans	
SF6: High amplitude discontinuous reflectors	Channels	

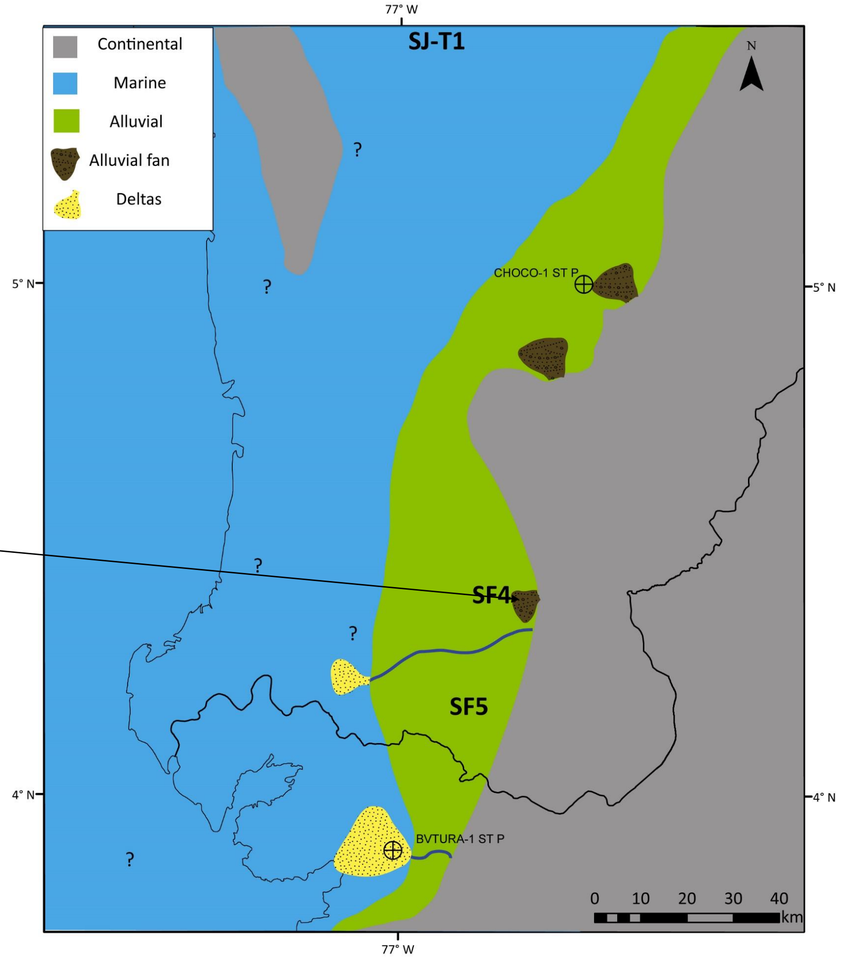


Age from Duque-Herrera et al. (2018)

SJ T1: ??? to ≈ 14Ma

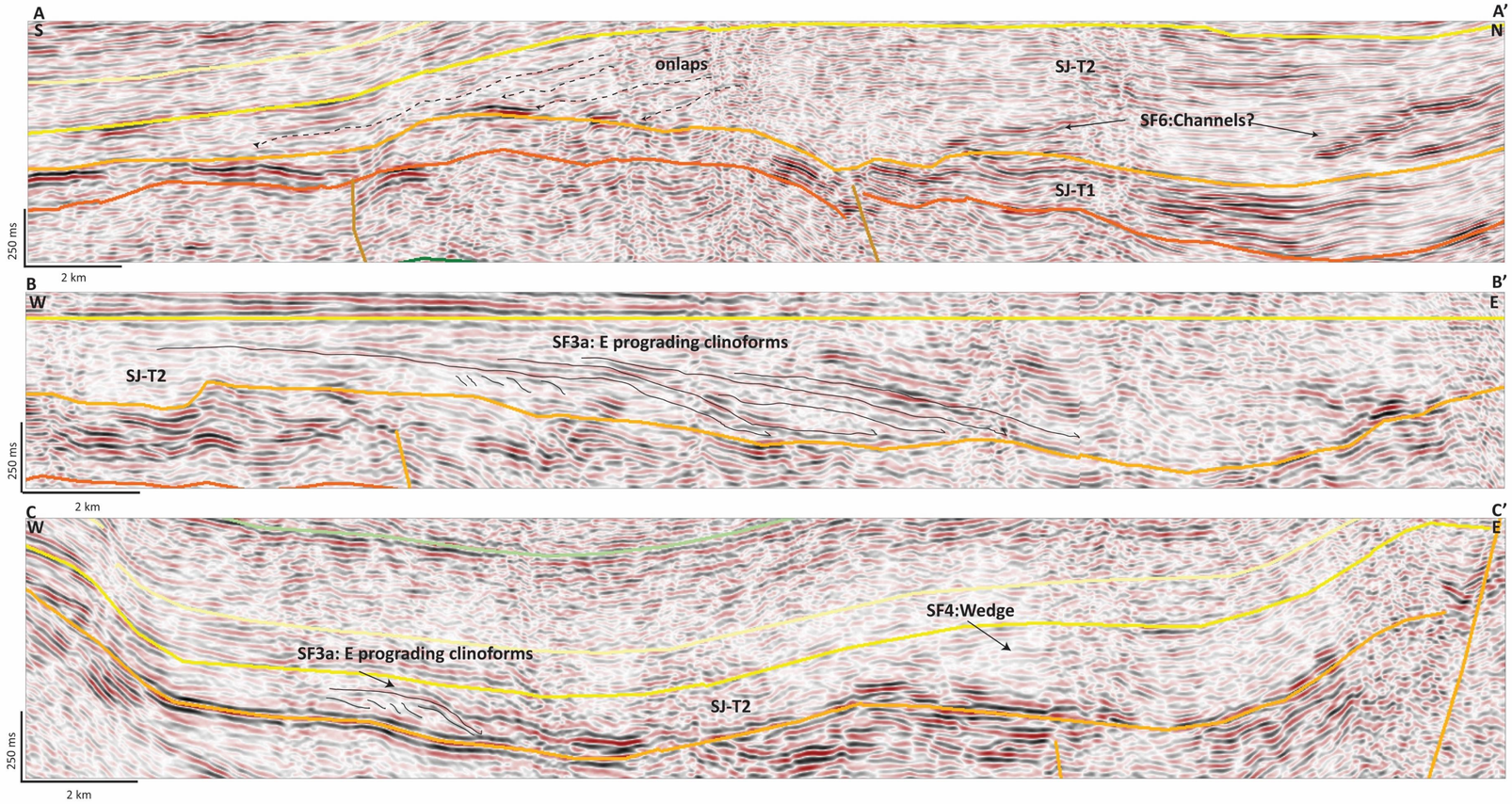
Active faults (FF1 and FF2) controlled the fan deposition in the area

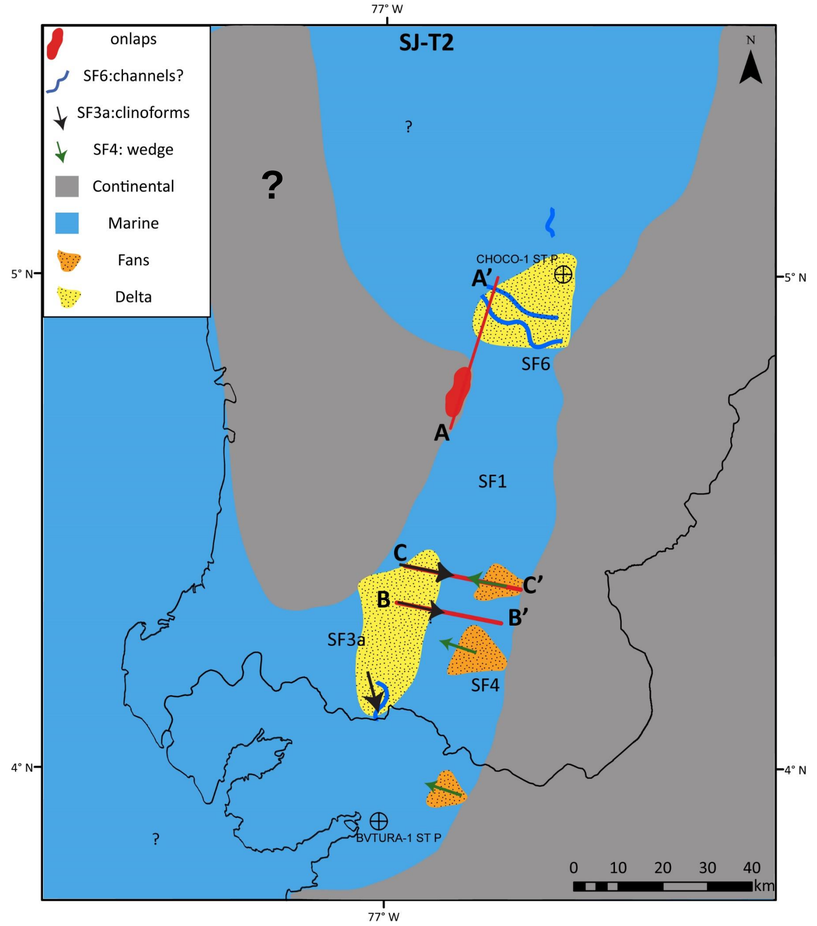




SJ T2: Aprox. 14 to ≈ 10 Ma

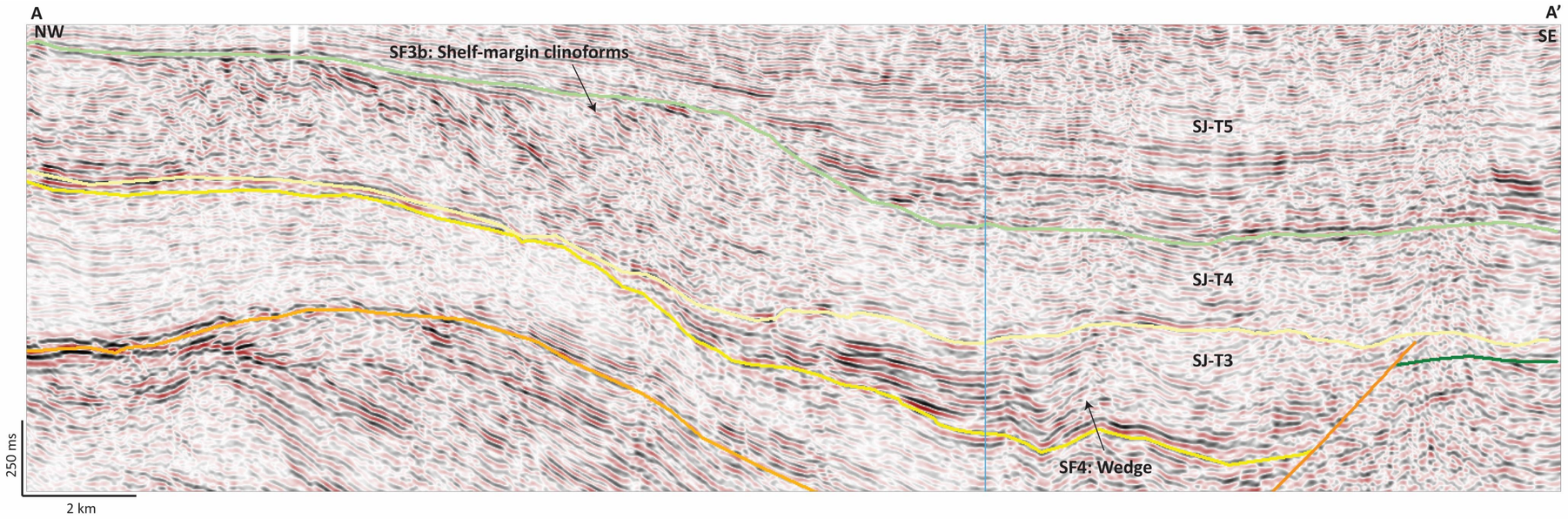
Two sources of sediments to the E and W. Deltas, structural controlled fans and channels are interpreted

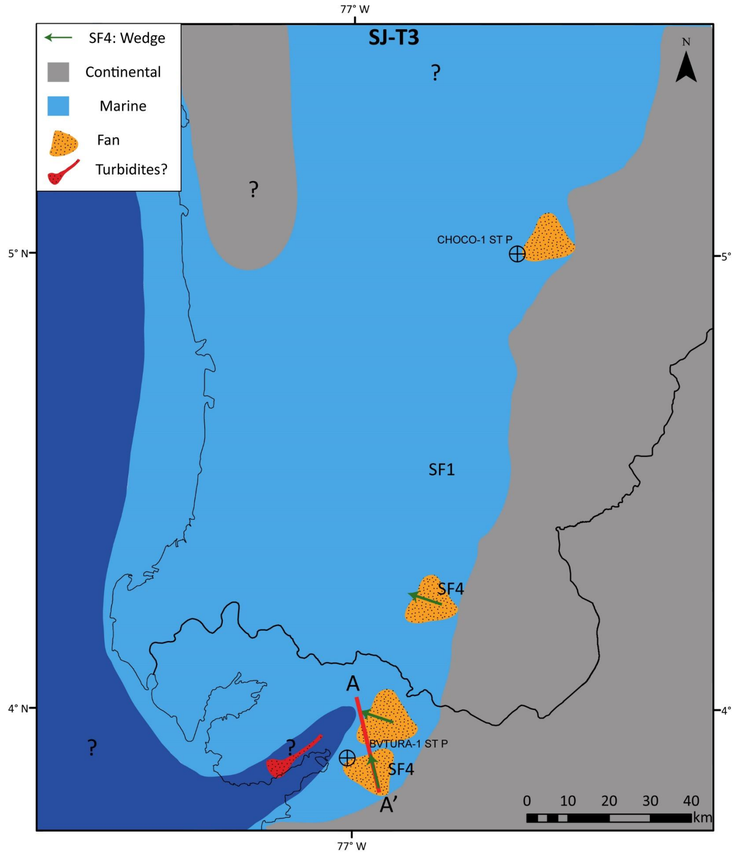




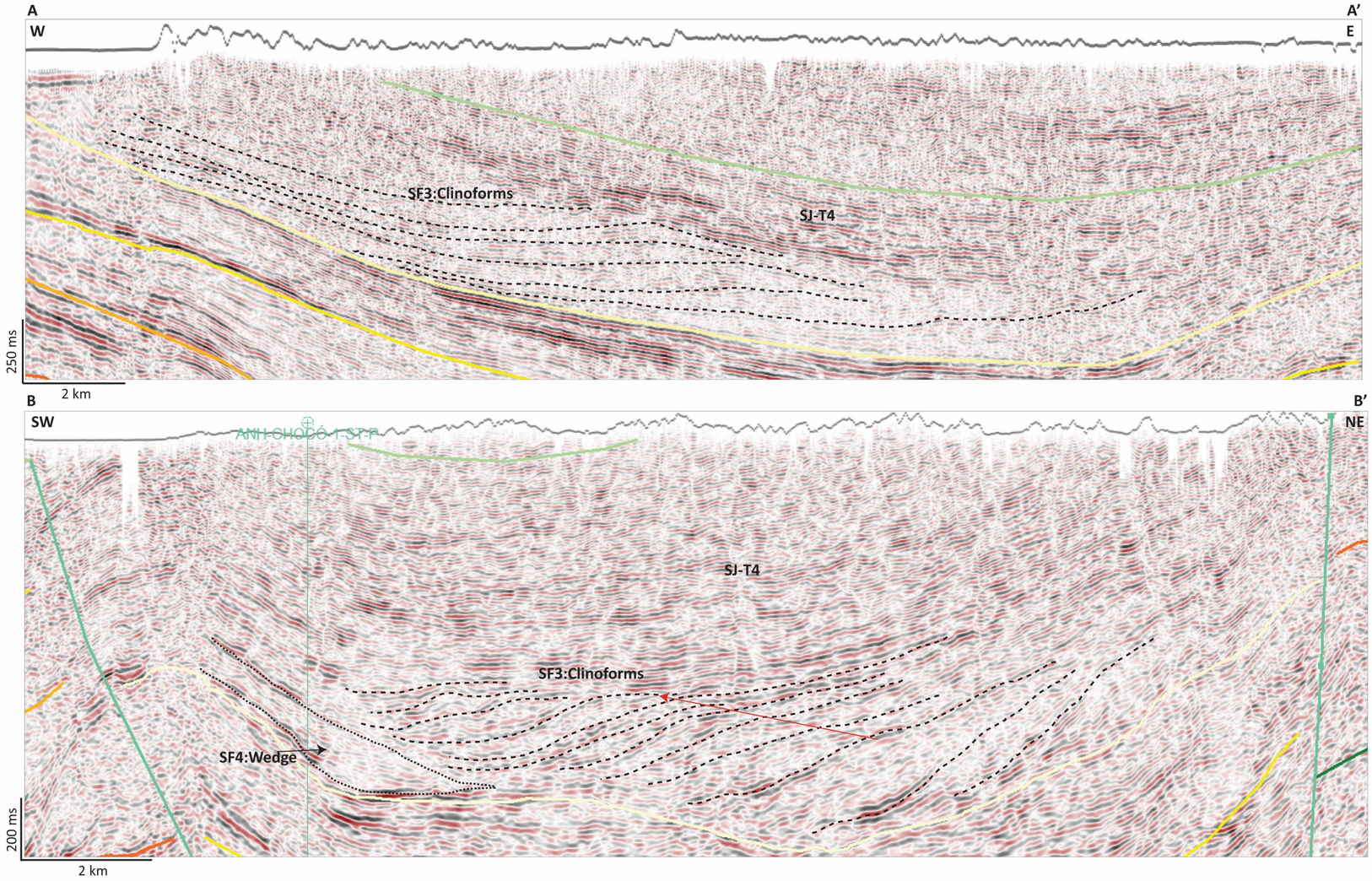
SJ T3: Aprox. 10 to ≈ 7 Ma

Localized fans close to structural highs

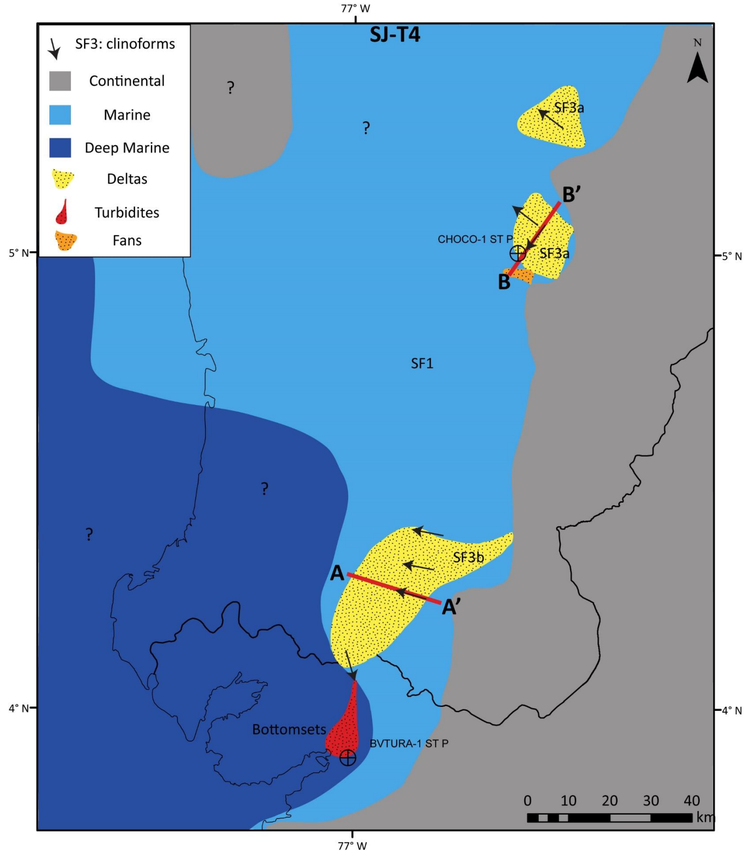




SJ T4: Aprox. 7 to ≈ 5 Ma

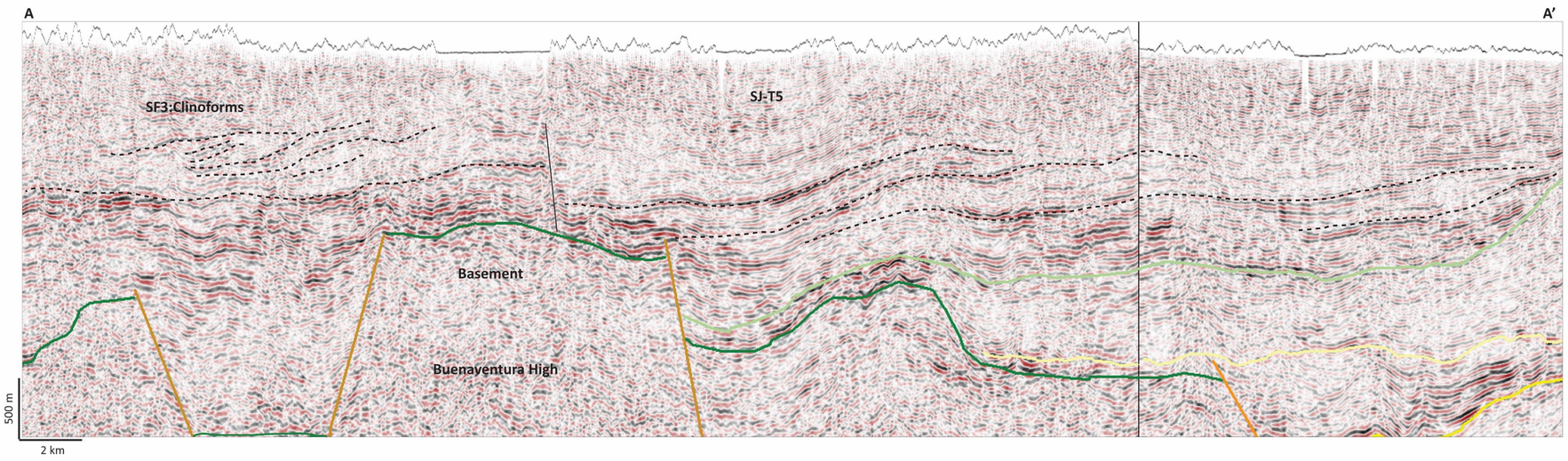


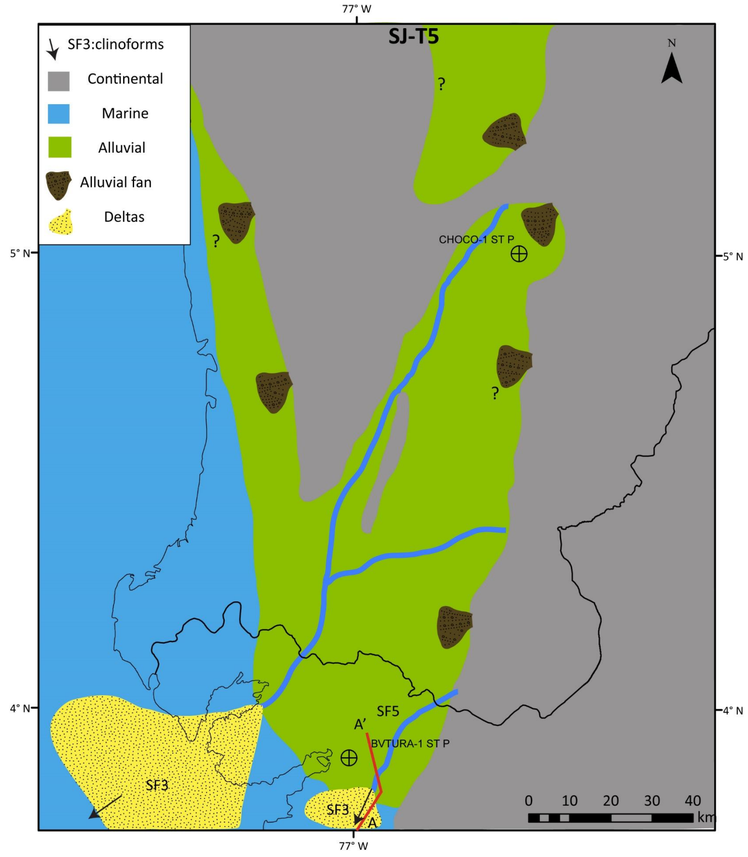
Two preferential sediment input areas: the Garrapatas fault and area close to the Choco-1 well



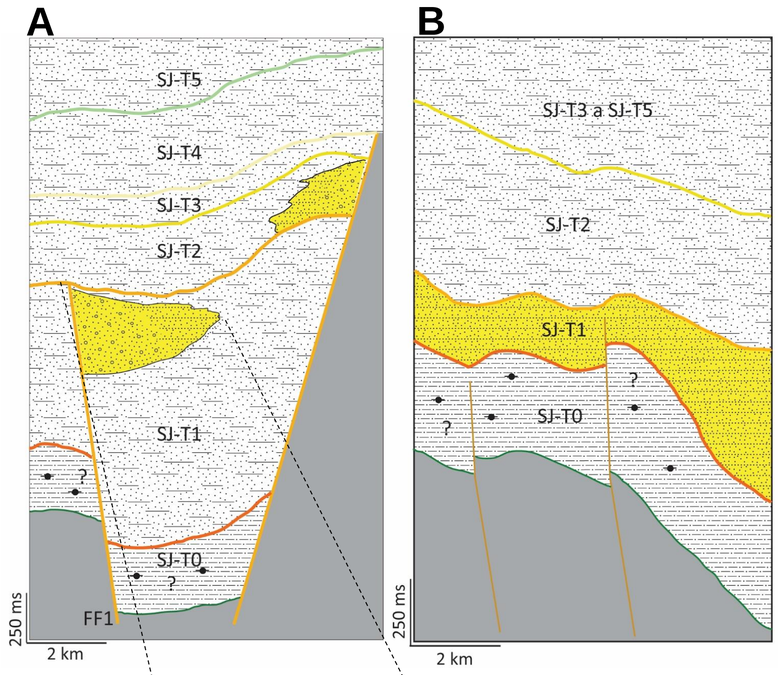
SJ T5: Younger than ≈ 5 Ma

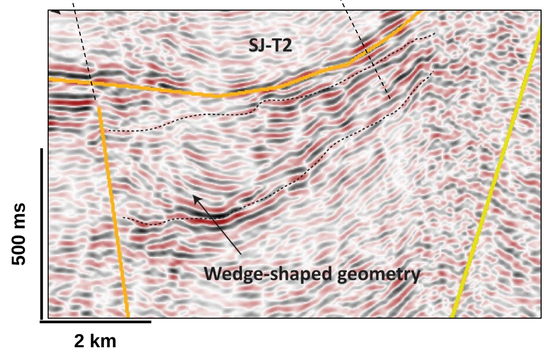
Fault reactivation,
continental environments dominated the basin,
the Buenaventura high was flooded.

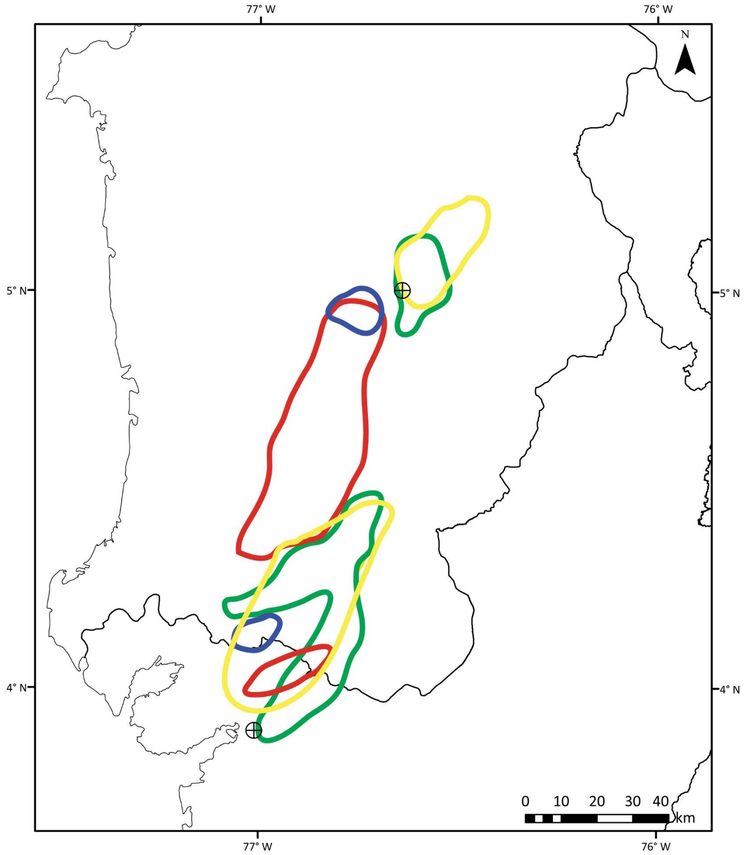


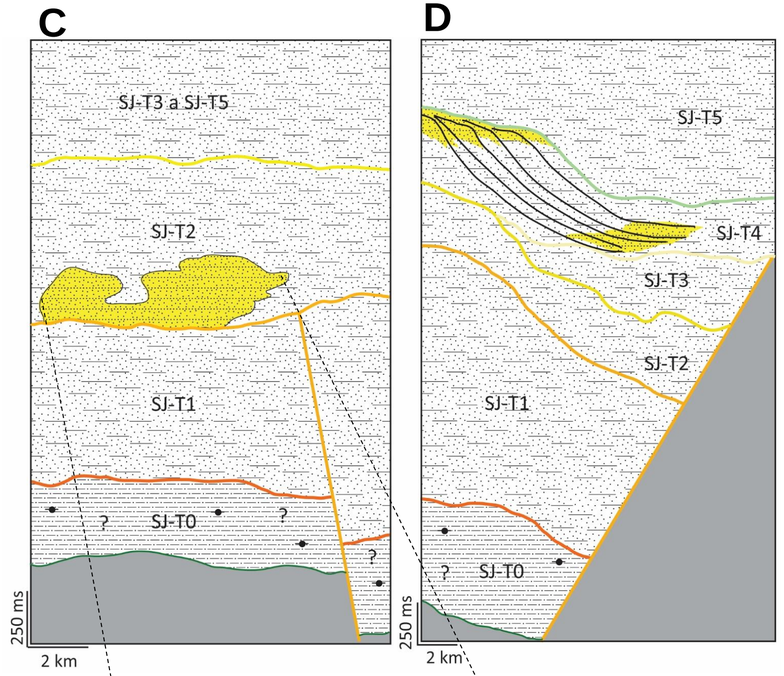


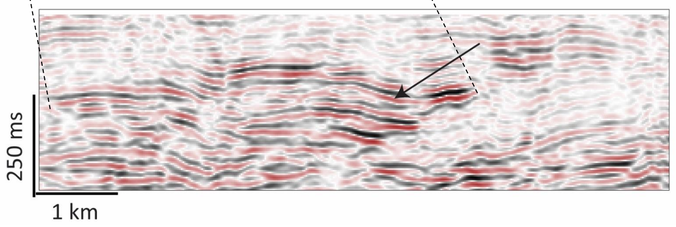
Structural and stratigraphic traps











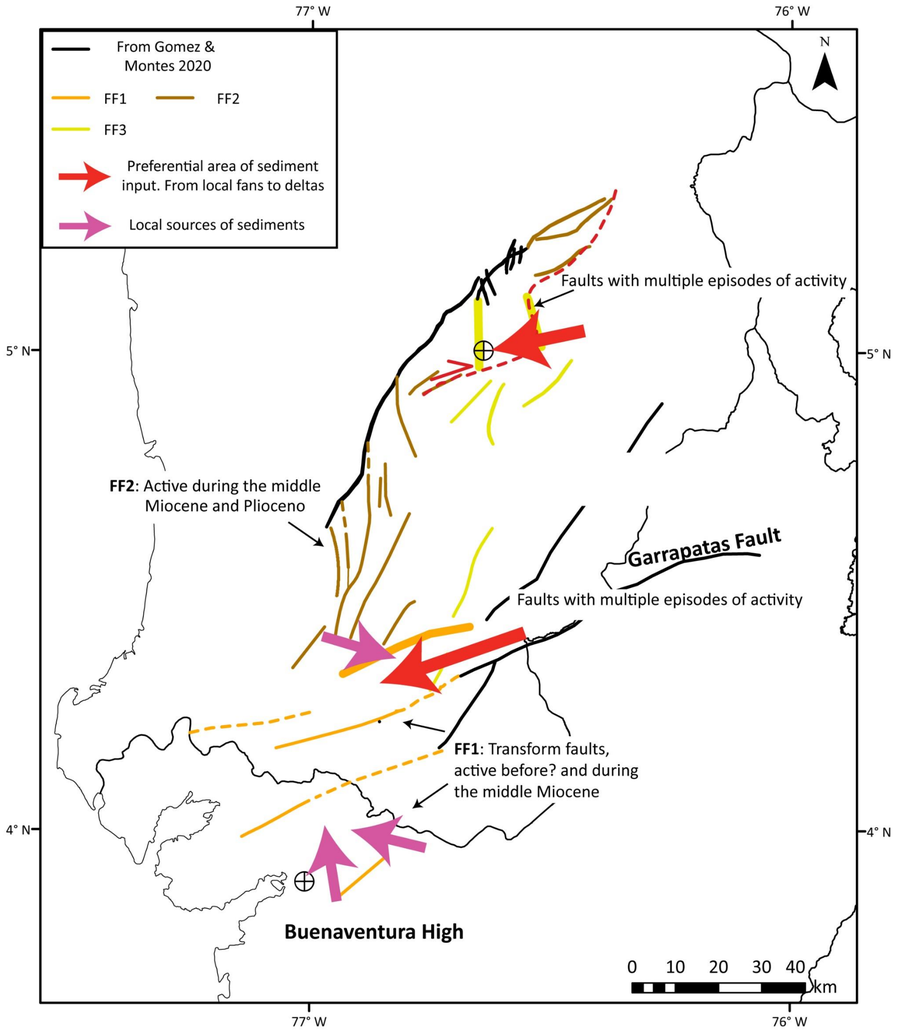
A. Structural traps related to fault families FF1 or FF3, deltaic or fan reservoirs of sequences SJ-T1, SJ-T2

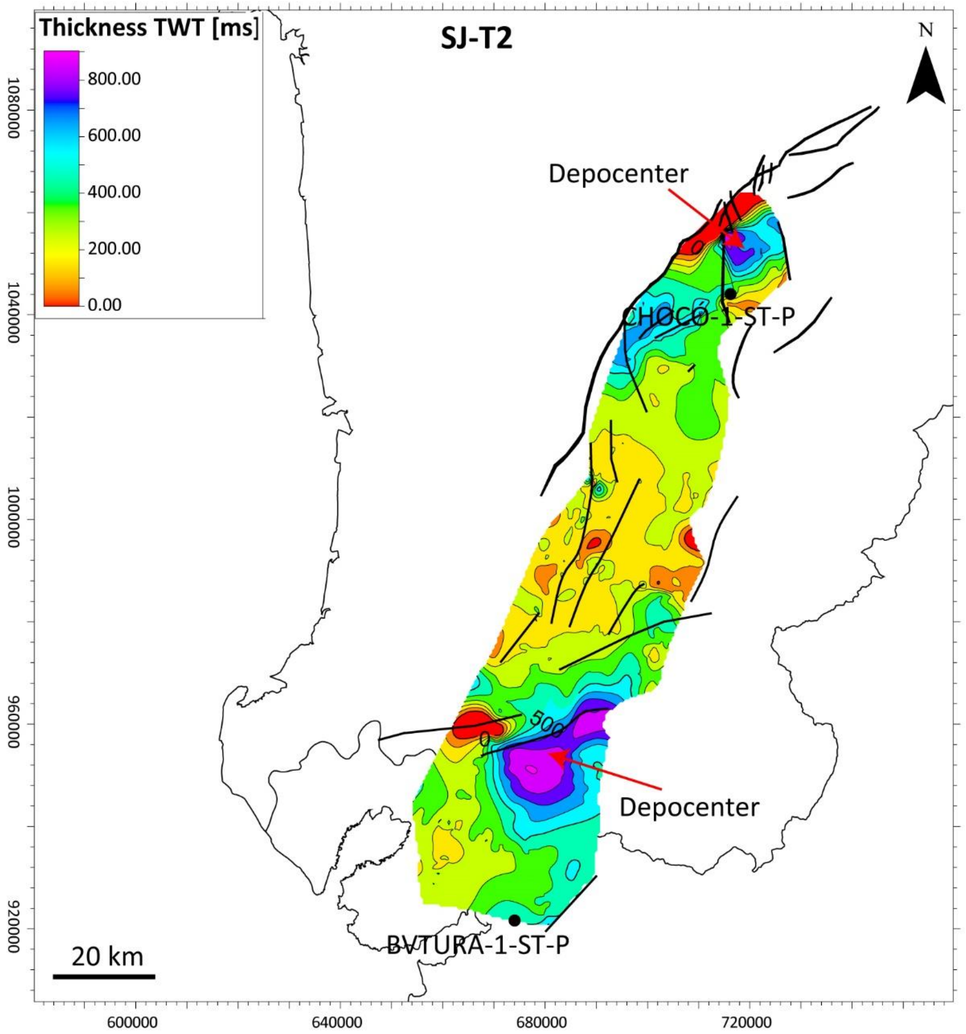
B. Structural traps related to anticlines, deltaic or fan reservoirs of sequences SJ-T1 y SJ-T2

C. Stratigraphic traps, in possible channels in sequence SJ-T2

D. Stratigraphic traps, in clinoforms in sequences SJ-T2, SJ-T4

How was the interaction between tectonics and sedimentation in the basin?





Conclusions

- 3 main fault families were identified in the study area.
- Two main tectonic events affected the basin during the middle Miocene and Pliocene to recent time.
- Faults with multiple episodes of activity were preferential areas of sediment input: the Garrapatas fault and the faults in subbasin close to the Choco-1 well.
- Based on seismic facies and scarce well data the following potential reservoirs are proposed: reservoir associated to deltaic environments, turbidite, localized fans and channels?
- Both structural and stratigraphic traps are feasible in the basin.

5. Organic geochemical integrated study

By Jorge Cortez, PhD

COLOMBIA ROUND 2021

ANALYTICAL SCHEME APPLIED TO ROCKS & BITUMEN EXTRACTS

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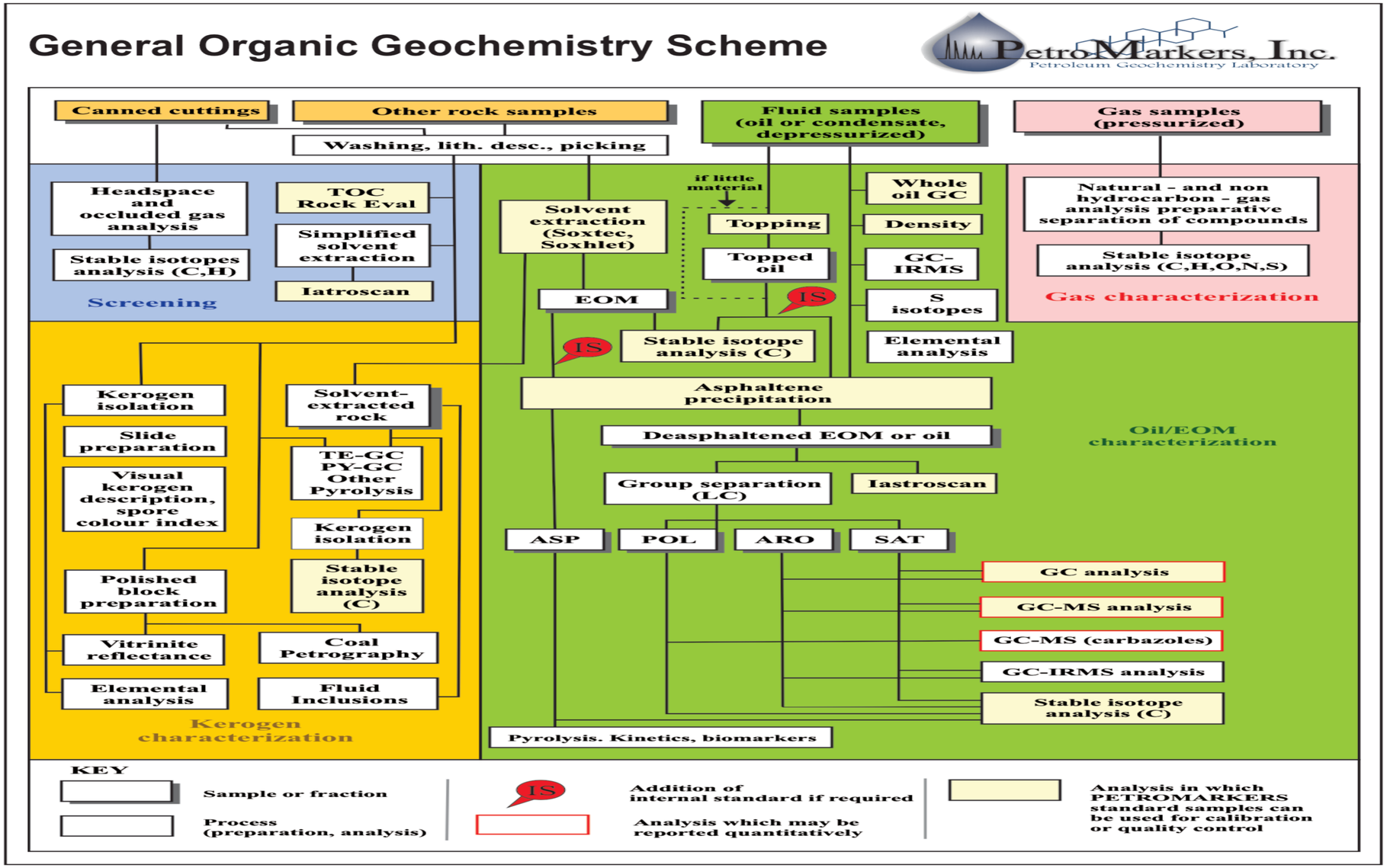
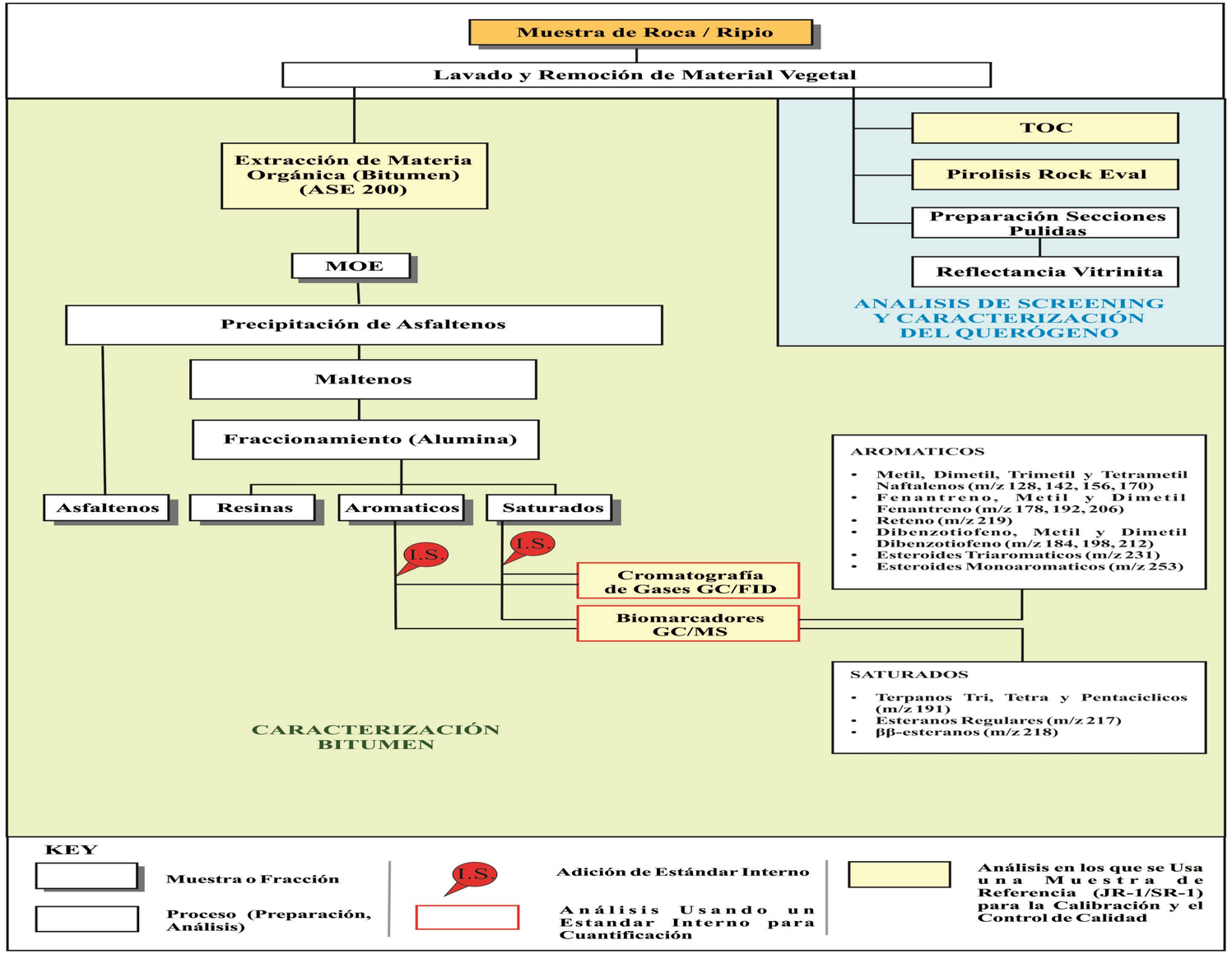


ANALYTICAL SCHEME APPLIED TO ROCKS & BITUMEN EXTRACTS



COLOMBIA ROUND 2021

TOC vs DEPTH (FT) IN THE TUMACO BASIN ROCKS

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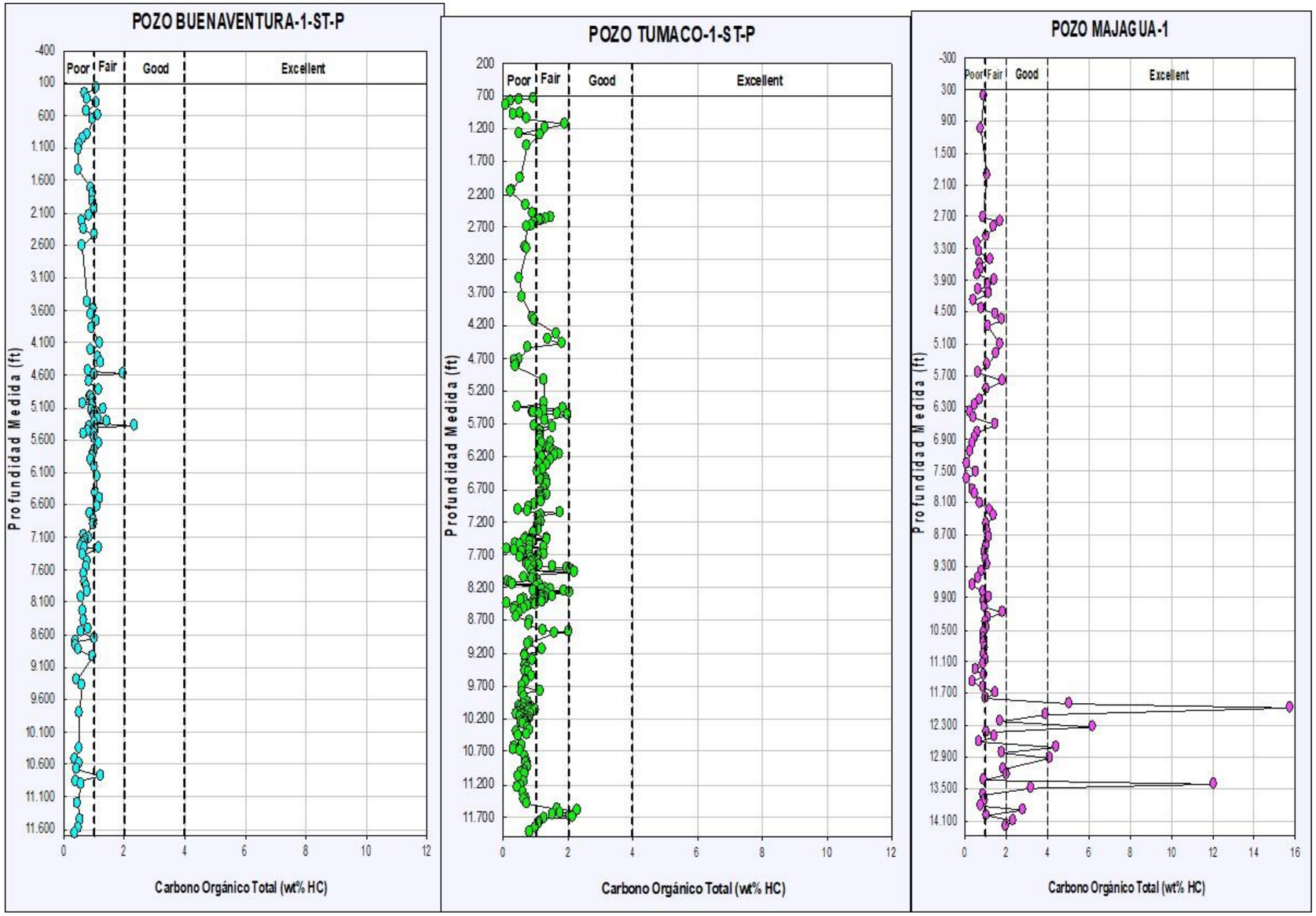

COLOMBIA ROUND 2021

TOC vs DEPTH (FT) IN THE TUMACO & SAN JUAN-ATRATO BASIN ROCKS

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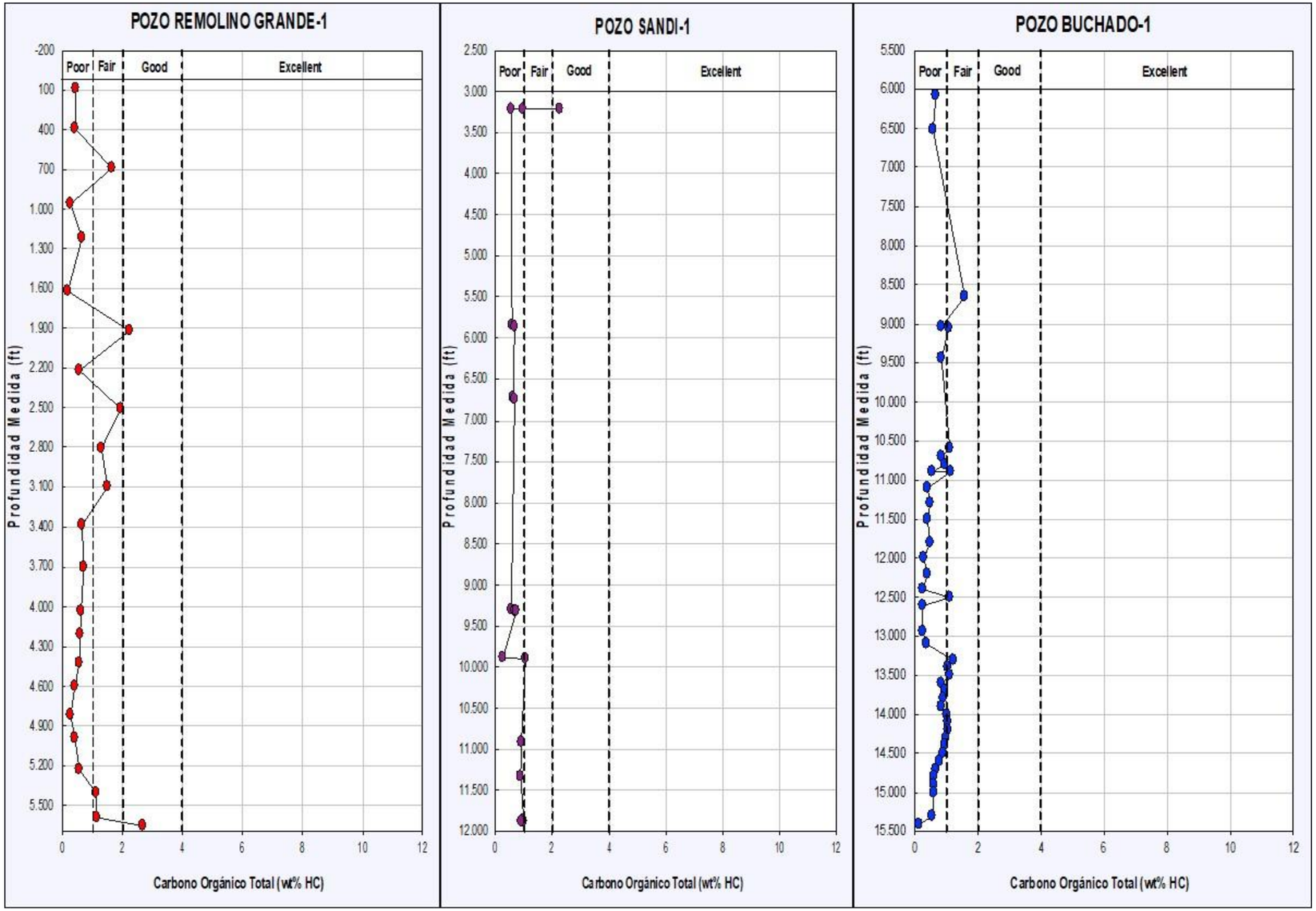
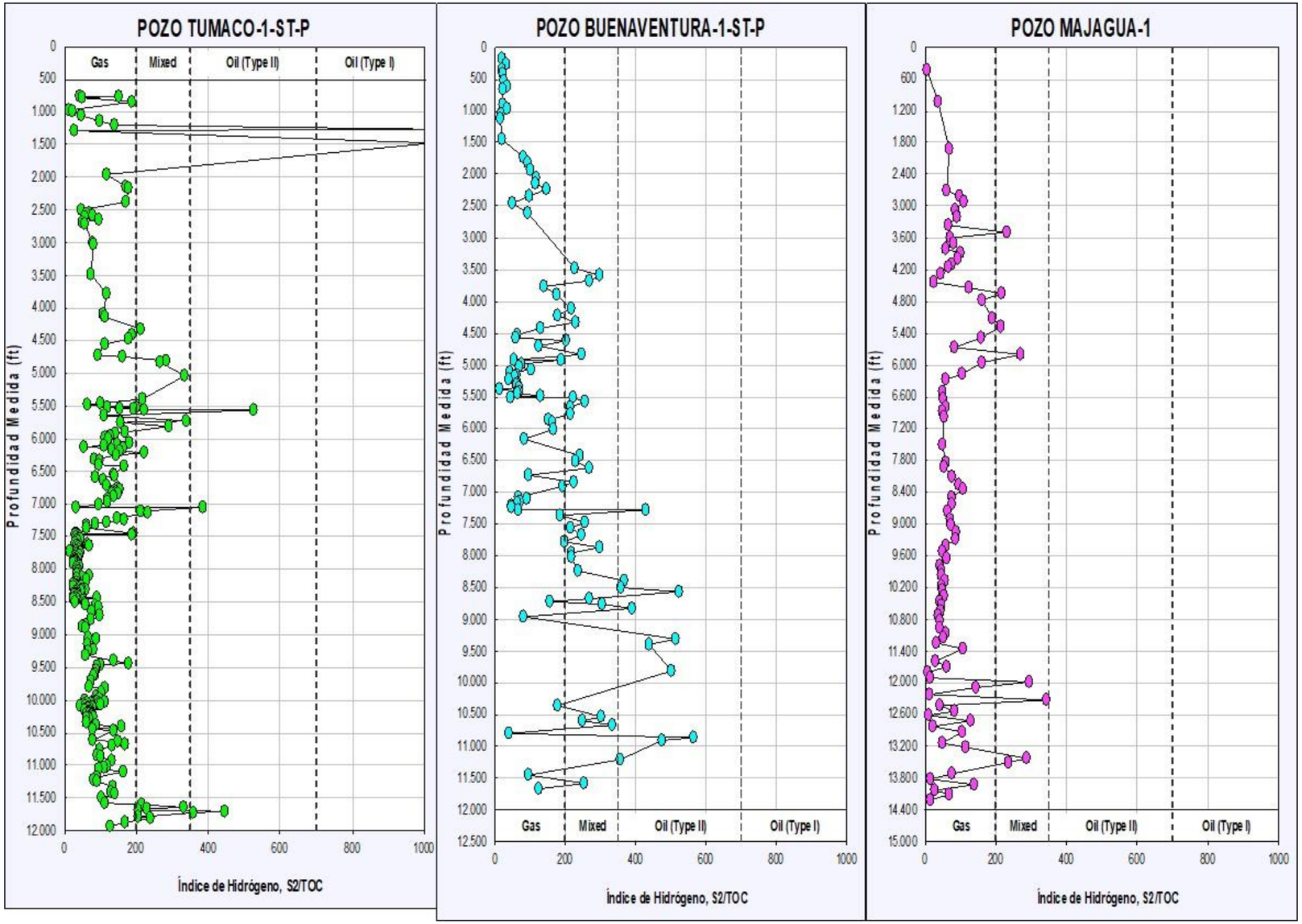
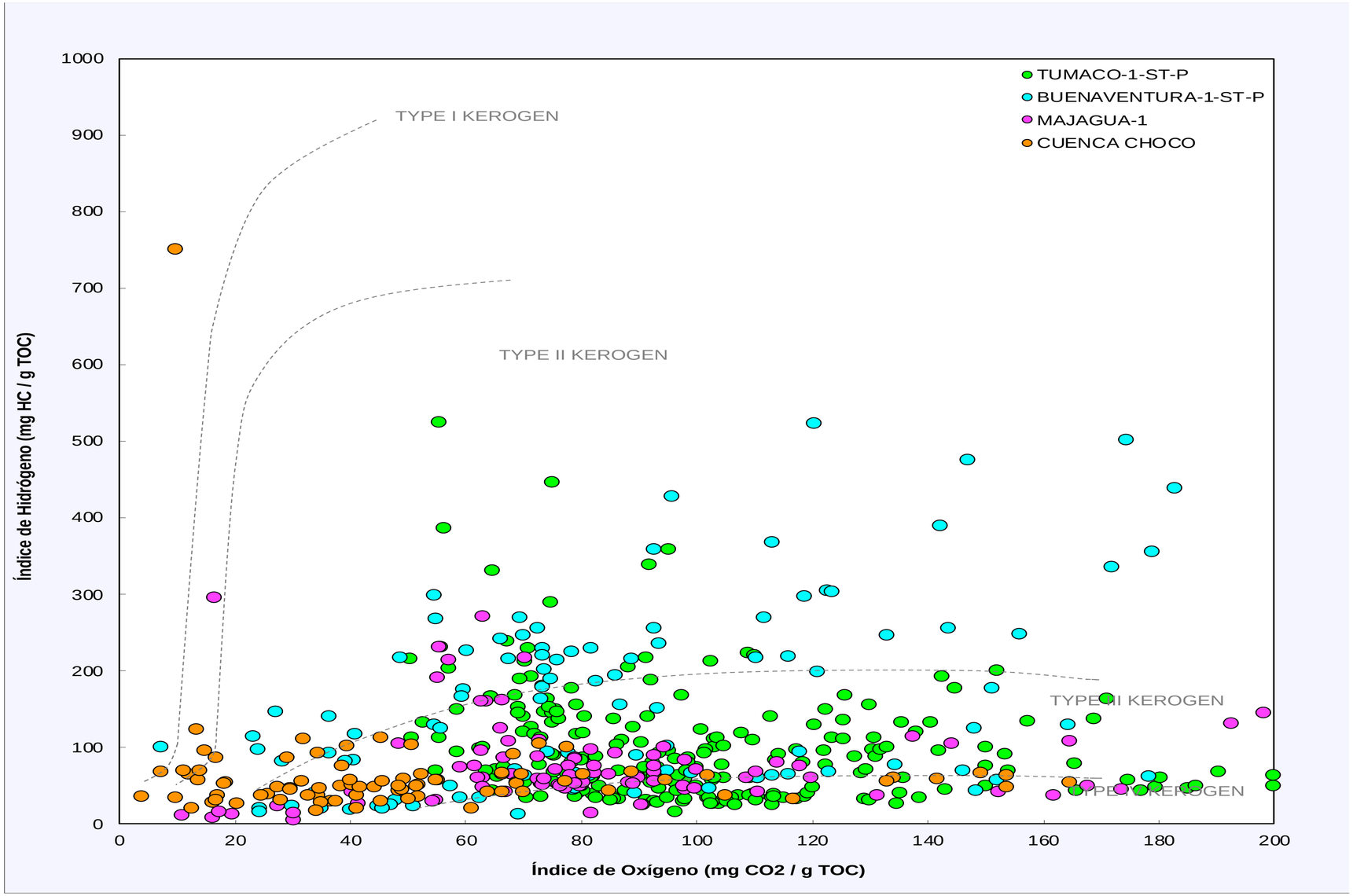


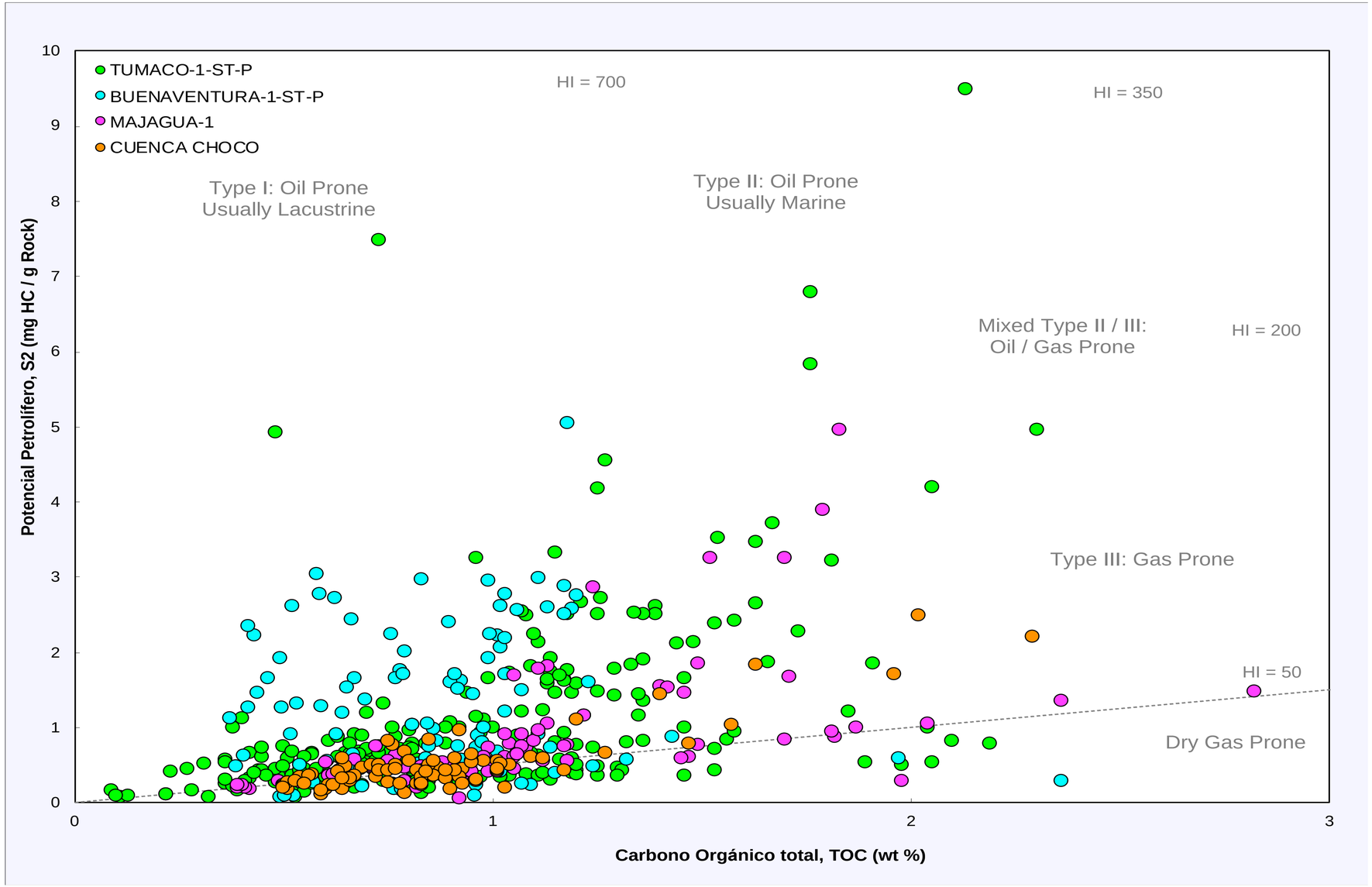
I.H. vs DEEP (FT) IN THE TUMACO BASIN ROCKS



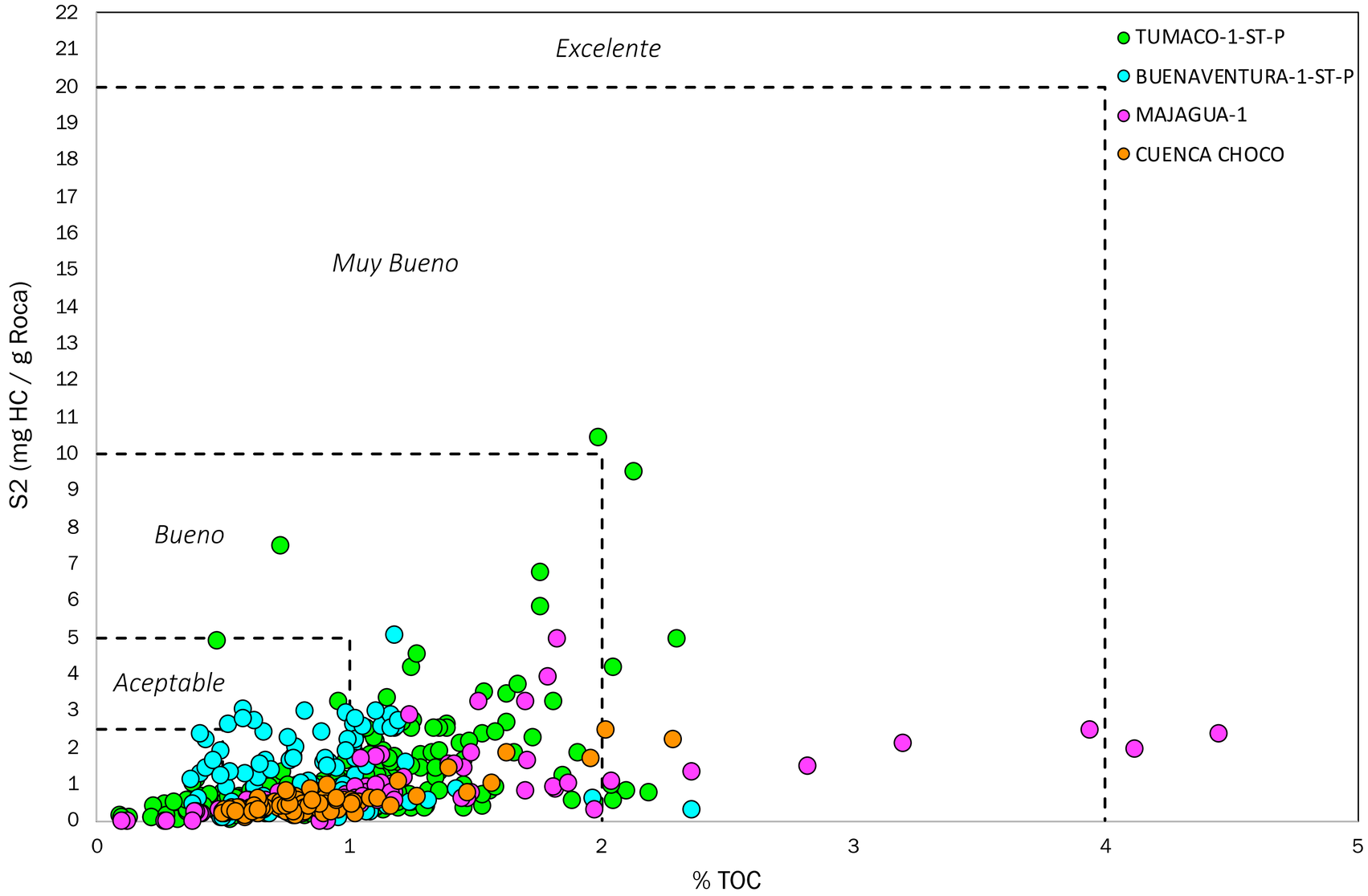
KEROGEN TYPE & THERMAL MATURITY BASED ON I.H. VS Tmax FOR PACIFIC BASINS



PSEUDO VAN KREVELEN DIAGRAM IN THE TUMACO BASIN ROCKS



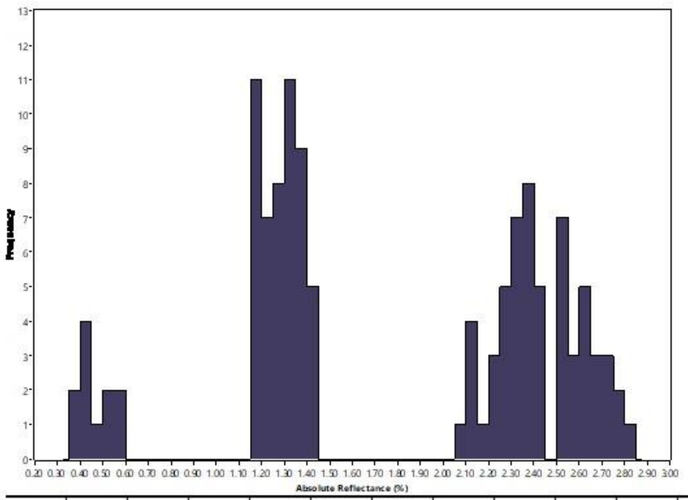
KEROGEN QUALITY BASED ON S2 (mg HC/g Roca) VS TOC, % IN THE TUMACO

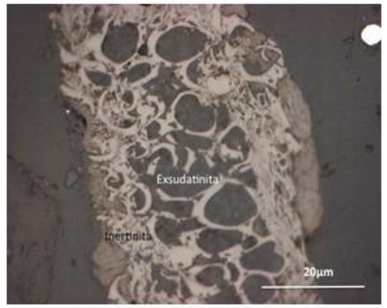


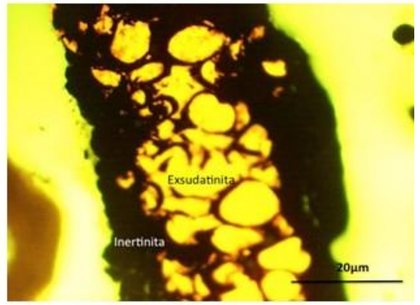
VITRINITE REFLECTANCE IN THE TUMACO BASIN ROCKS

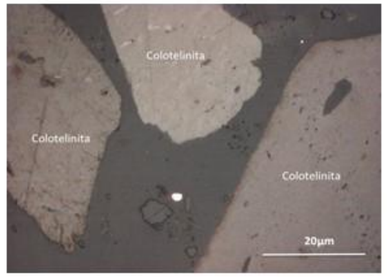
Muestra T-11710

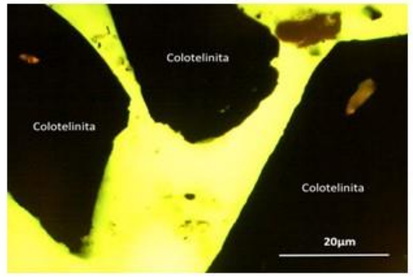
Tipo de muestra:	Materia orgánica dispersa
Tipo de maceral:	Vitrinita.
No. de Lecturas:	13
Total de lecturas:	151
Media:	0.47
Desv. Est:	0.0788
Máximo:	0.60
Mínimo:	0.38

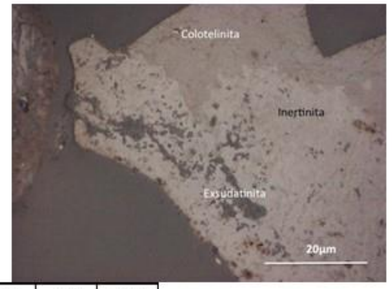


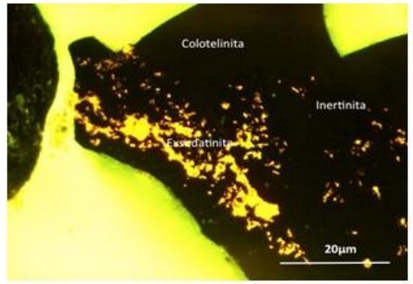






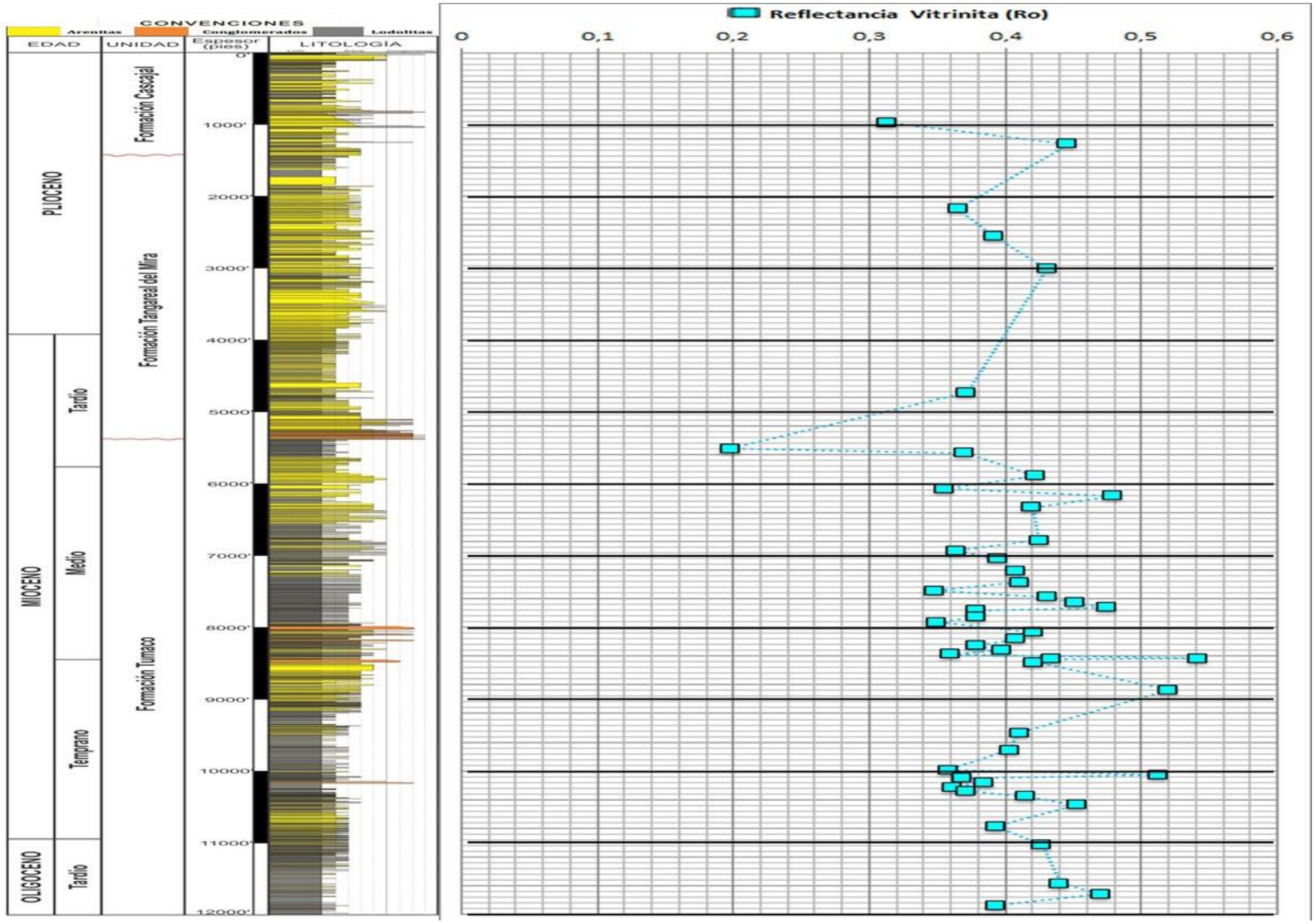






0.38	0.39	0.41	0.42	0.43	0.44	0.46	0.52	0.54	0.59	0.60	1.16	1.17	1.18
1.19	1.20	1.21	1.23	1.24	1.25	1.26	1.27	1.28	1.29	1.30	1.31	1.32	1.33
1.34	1.35	1.36	1.39	1.40	1.41	1.43	1.44	2.50	2.51	2.52	2.53	2.53	2.54
2.55	2.60	2.61	2.63	2.64	2.67	2.68	2.69	2.71	2.72	2.73	2.76	2.77	2.82

Ro VS DEPTH (FT), STRATIGRAPHIC COLUMN & AGE IN THE TUMACO BASIN



ORGANIC GEOCHEMISTRY OF THE BITUMINOUS EXTRACTS:

EOM, SARA, n-ALKANES

BIOMARKERS: TERPANES, STERANES & AROMATIC HYDROCARBONS

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TERNARY DIAGRAMS BASED ON SARA ANALYSIS IN TUMACO BASIN

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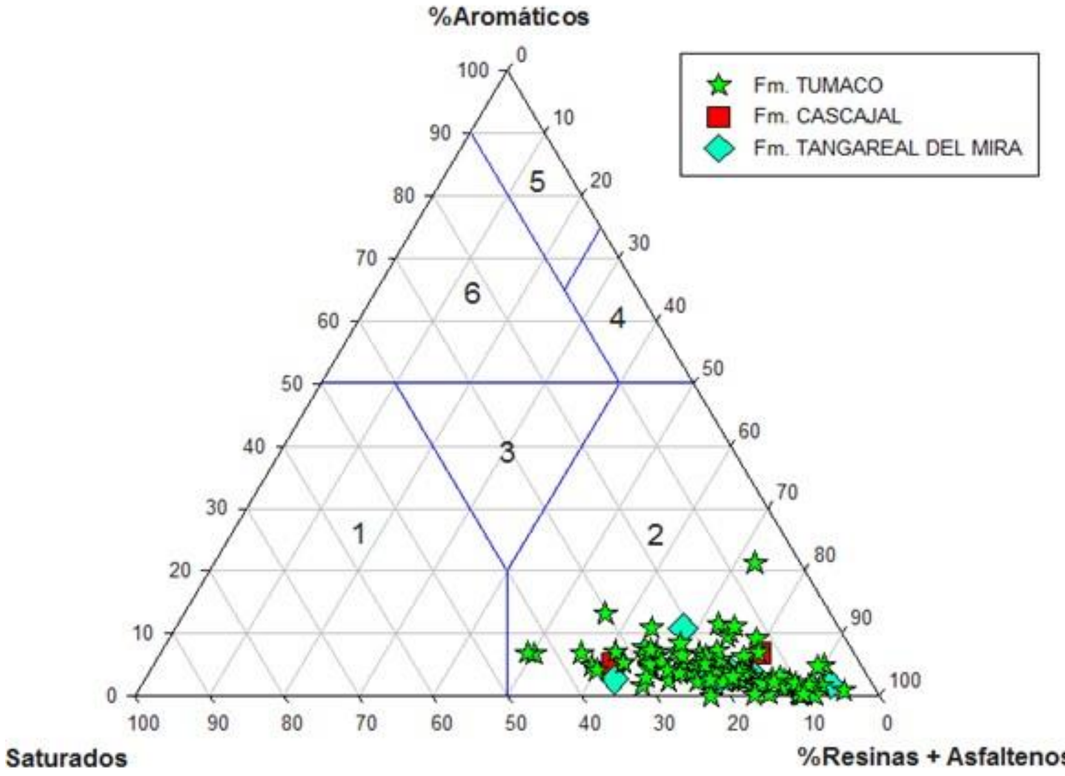
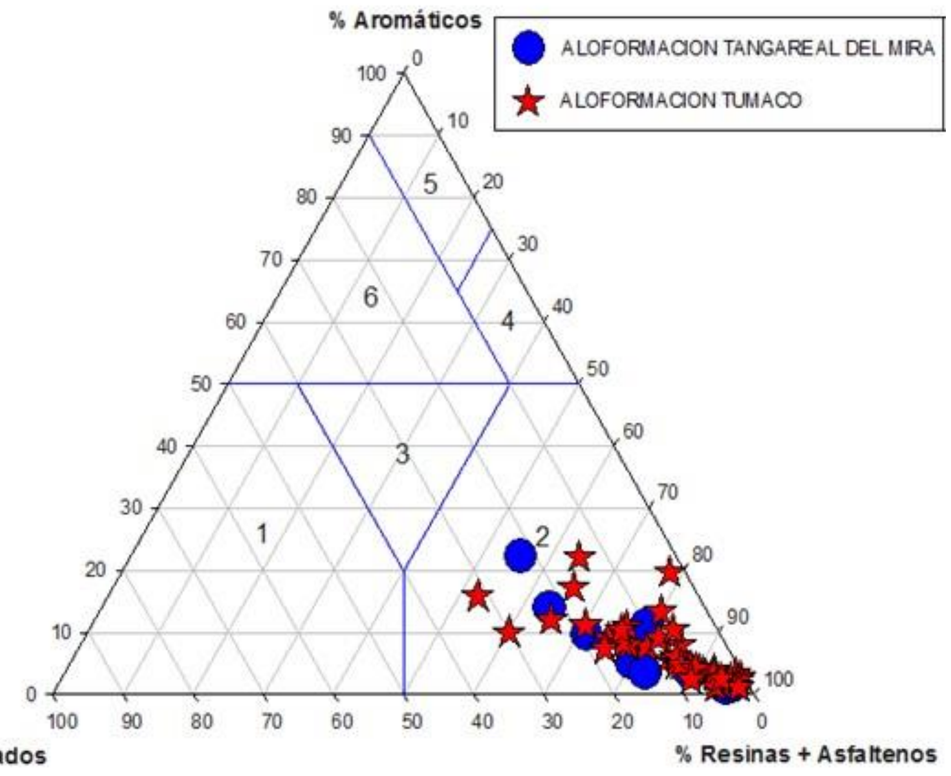
Tumaco ST-1-P well



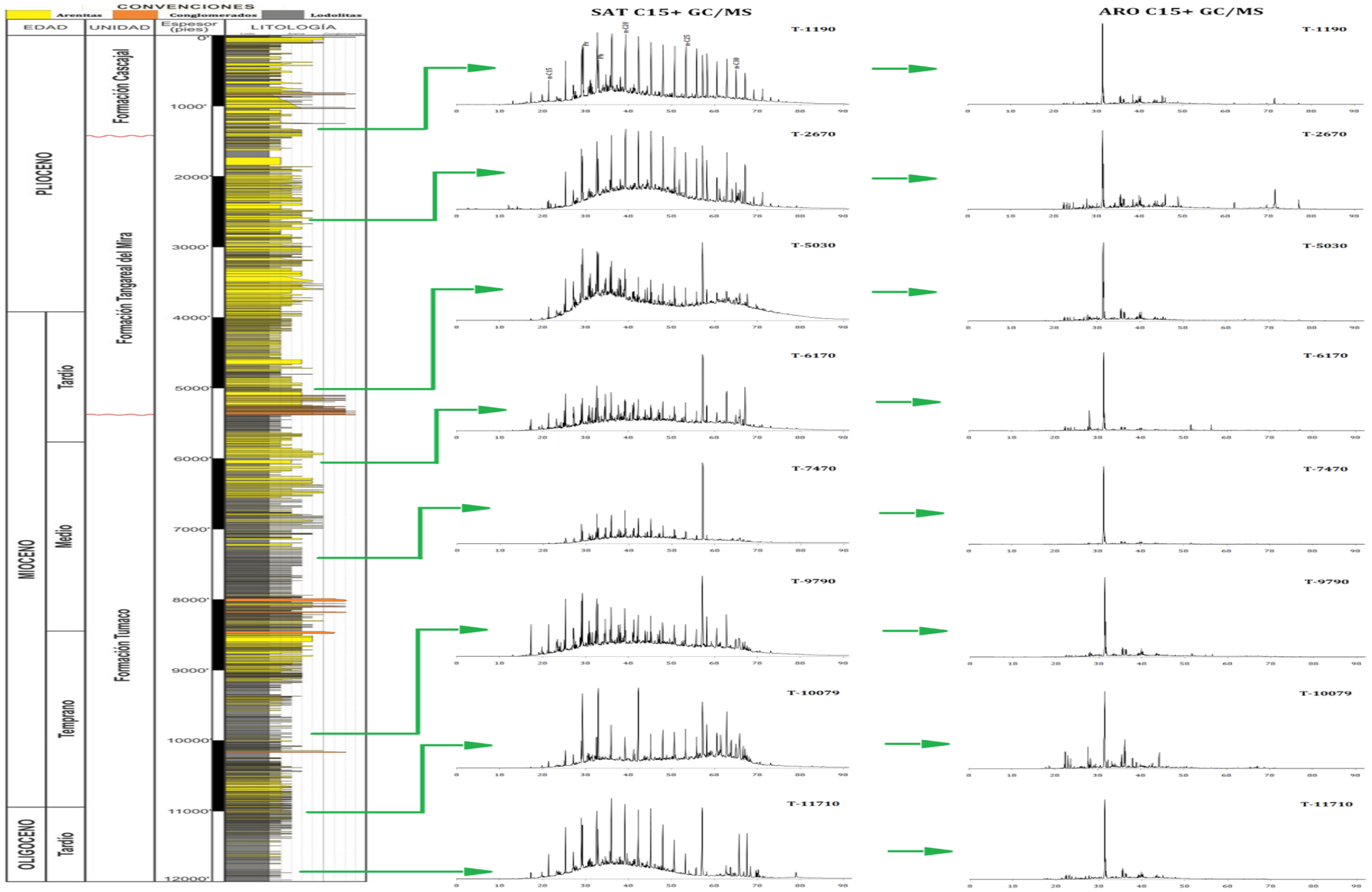
1. Parafínico	3. Parafínico - Nafténico	5. Aromático - Asfáltico
2. Nafténico	4. Aromático - Nafténico	6. Aromático intermedio

B/ventura ST-1-P well

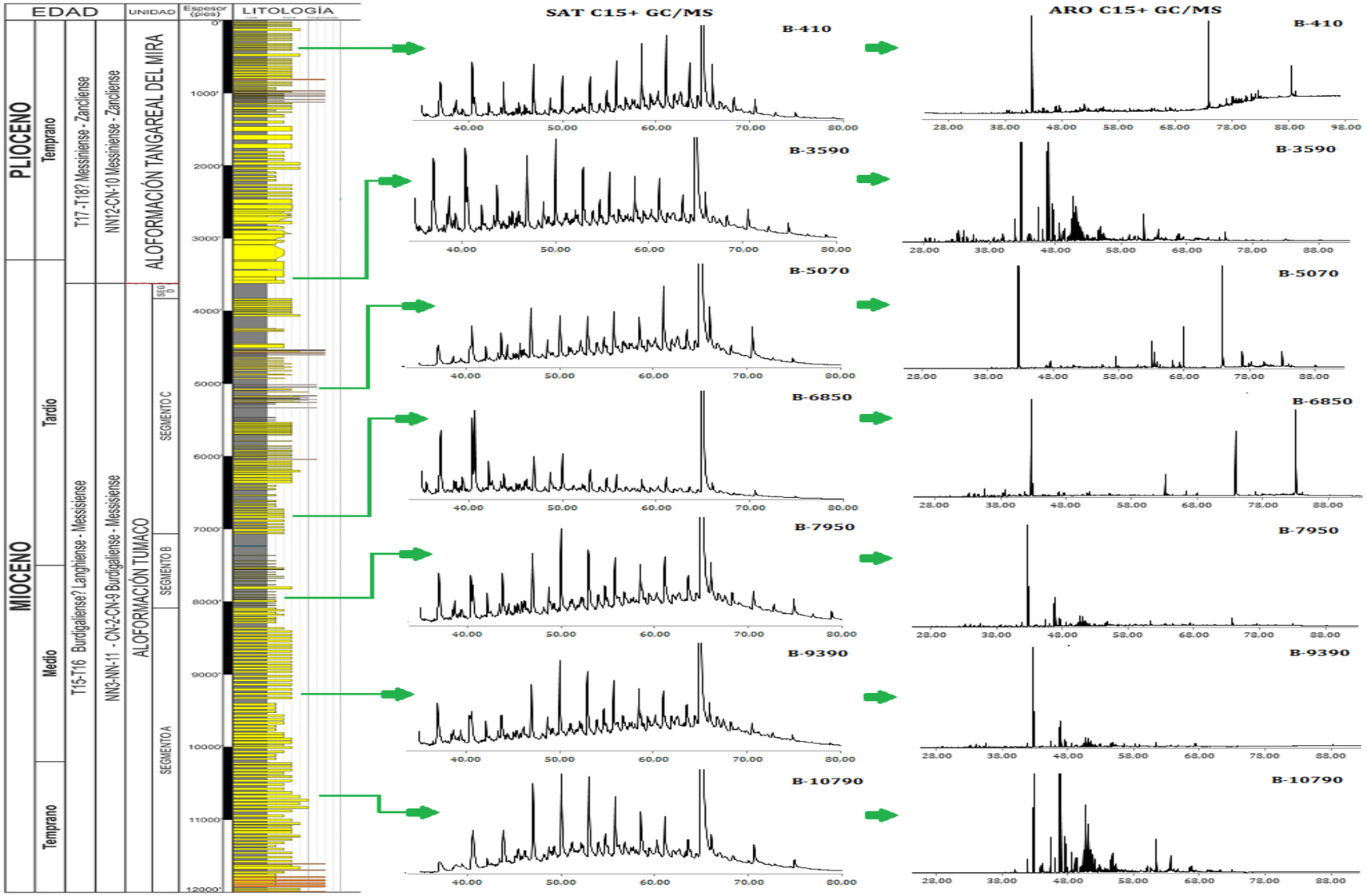


1. Parafínico	3. Parafínico - Nafténico	5. Aromático - Asfáltico
2. Nafténico	4. Aromático - Nafténico	6. Aromático intermedio

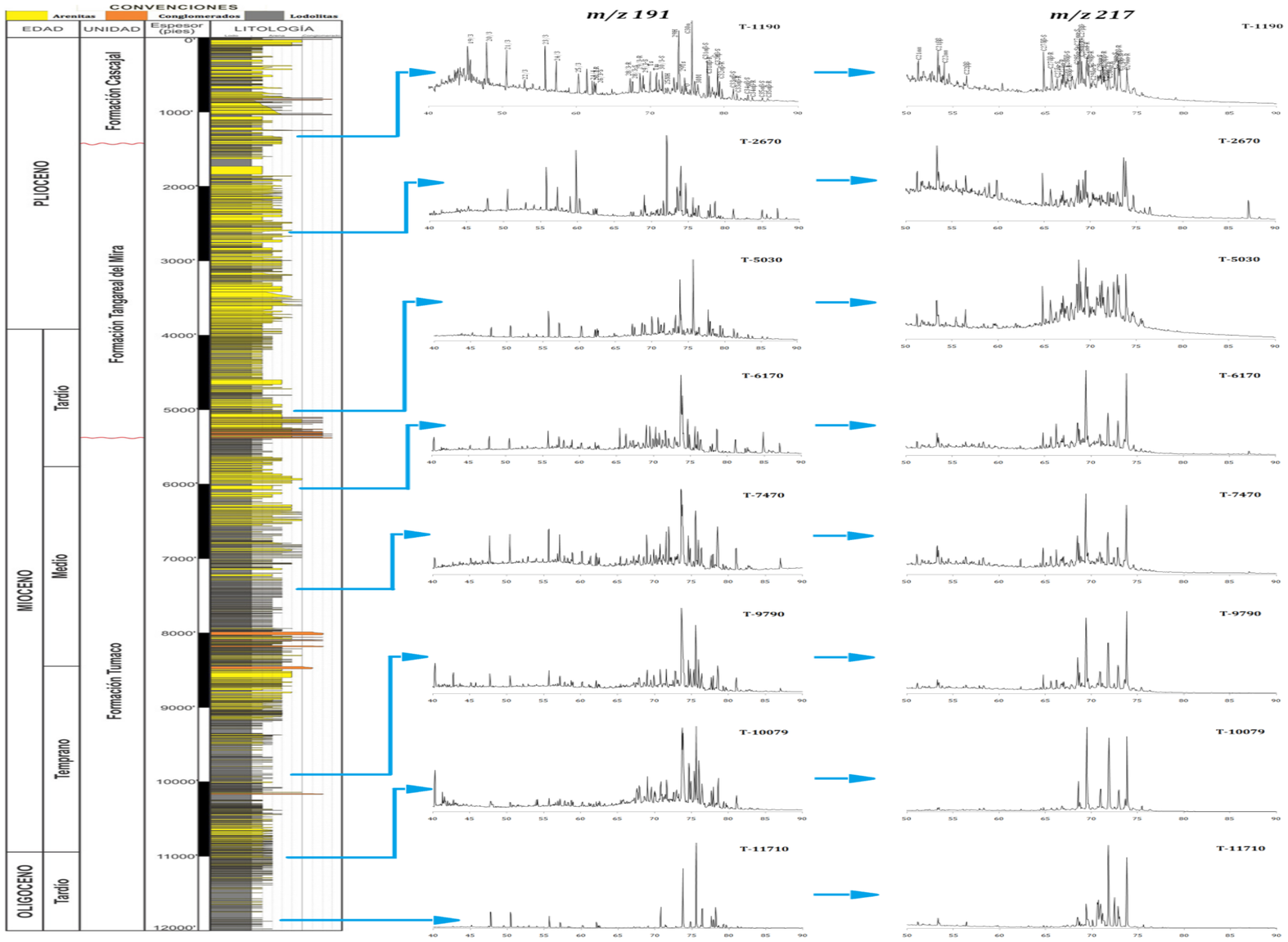
C_{15}^{+} n-ALKANES OF THE BITUMINOUS EXTRACTS FROM TUMACO-1-ST-P WELL



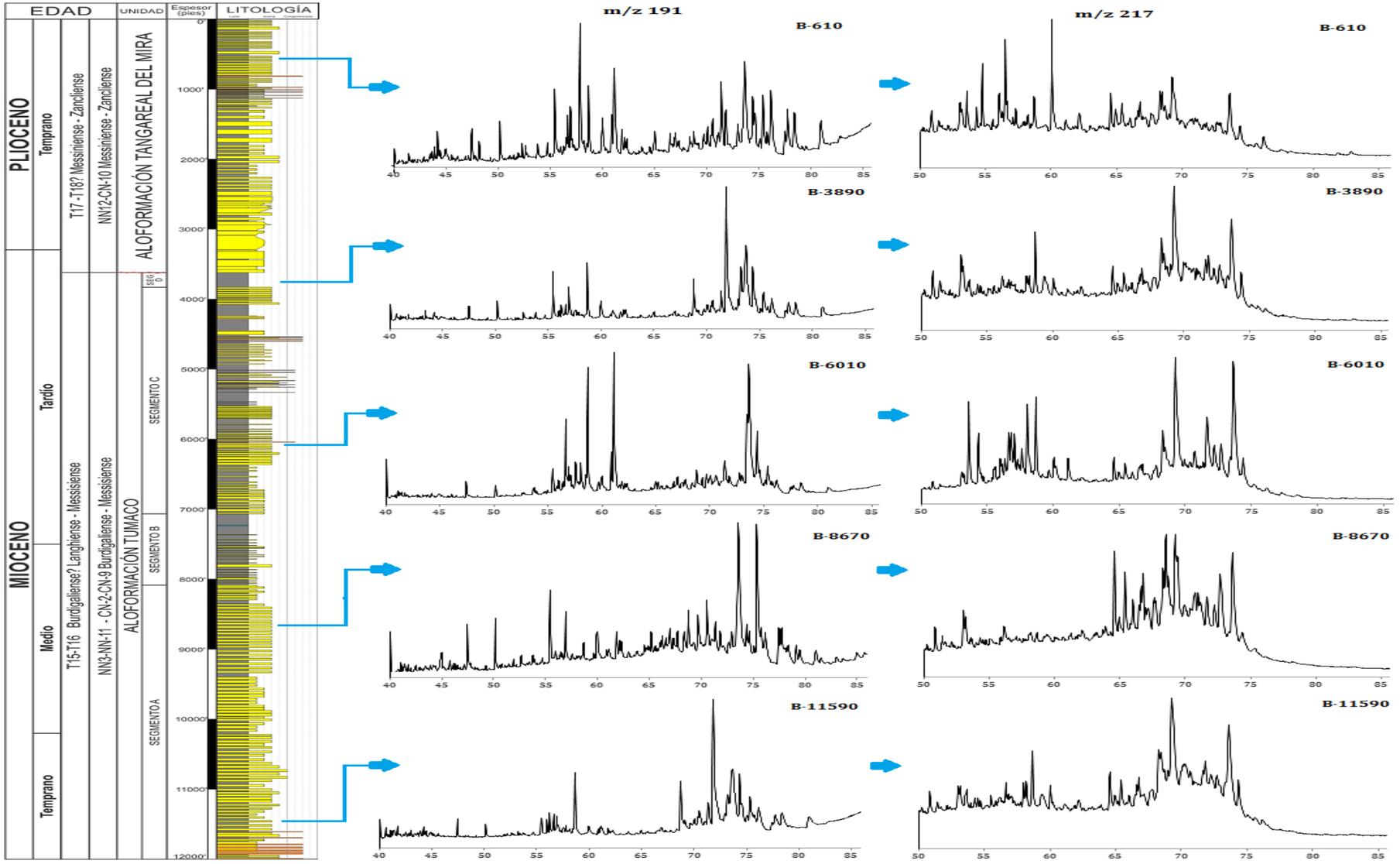
C_{15}^{+} n-ALKANES OF THE BITUMINOUS EXTRACTS FROM B/VENTURA-1-ST-P WELL



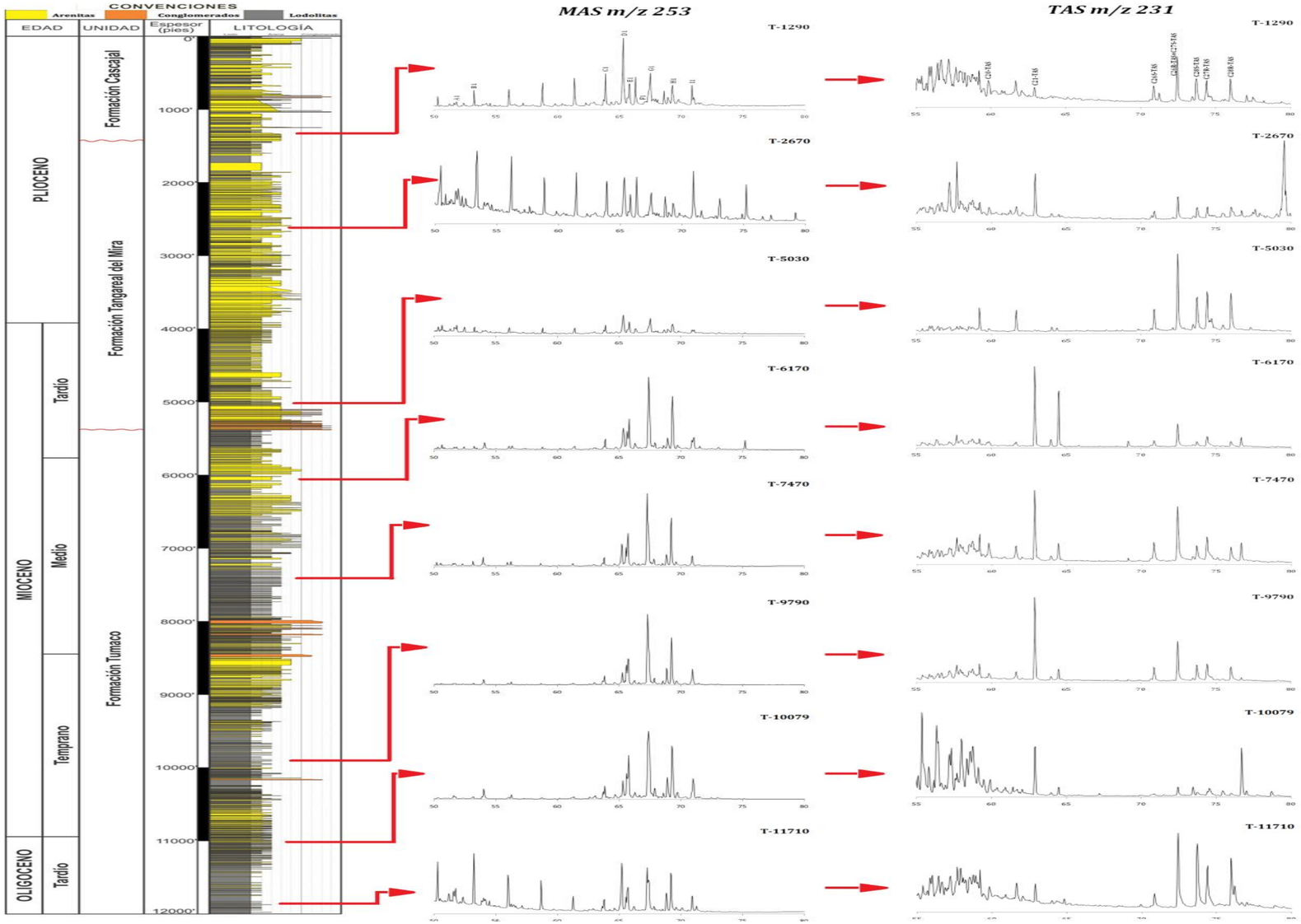
TERPANES & STERANES OF THE BITUMINOUS EXTRACTS FROM TUMACO-1-ST-P WELL



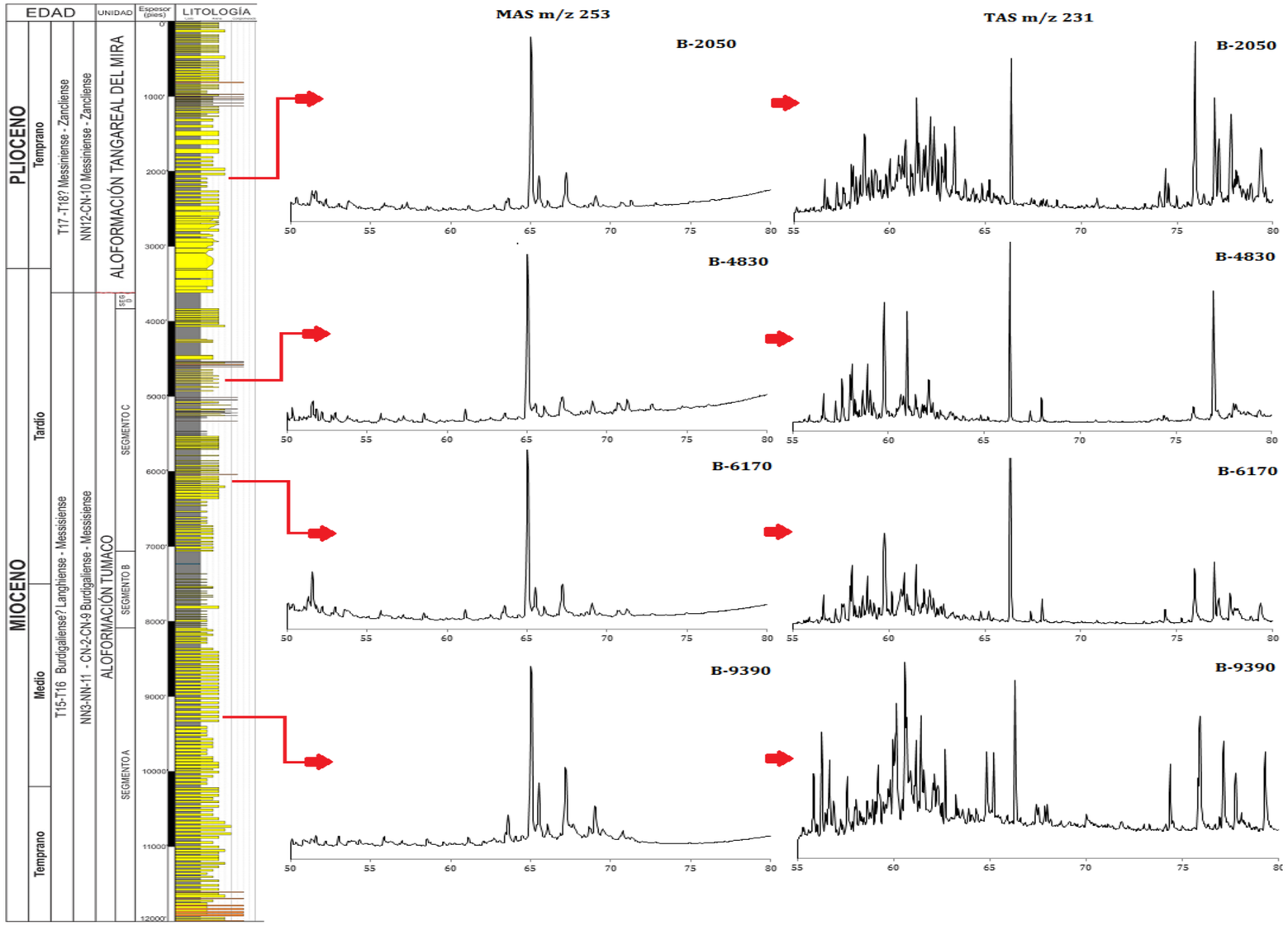
TERPANES & ESTERANES OF THE BITUMINOUS EXTRACTS FROM B/VENTURA-1-ST-P WELL



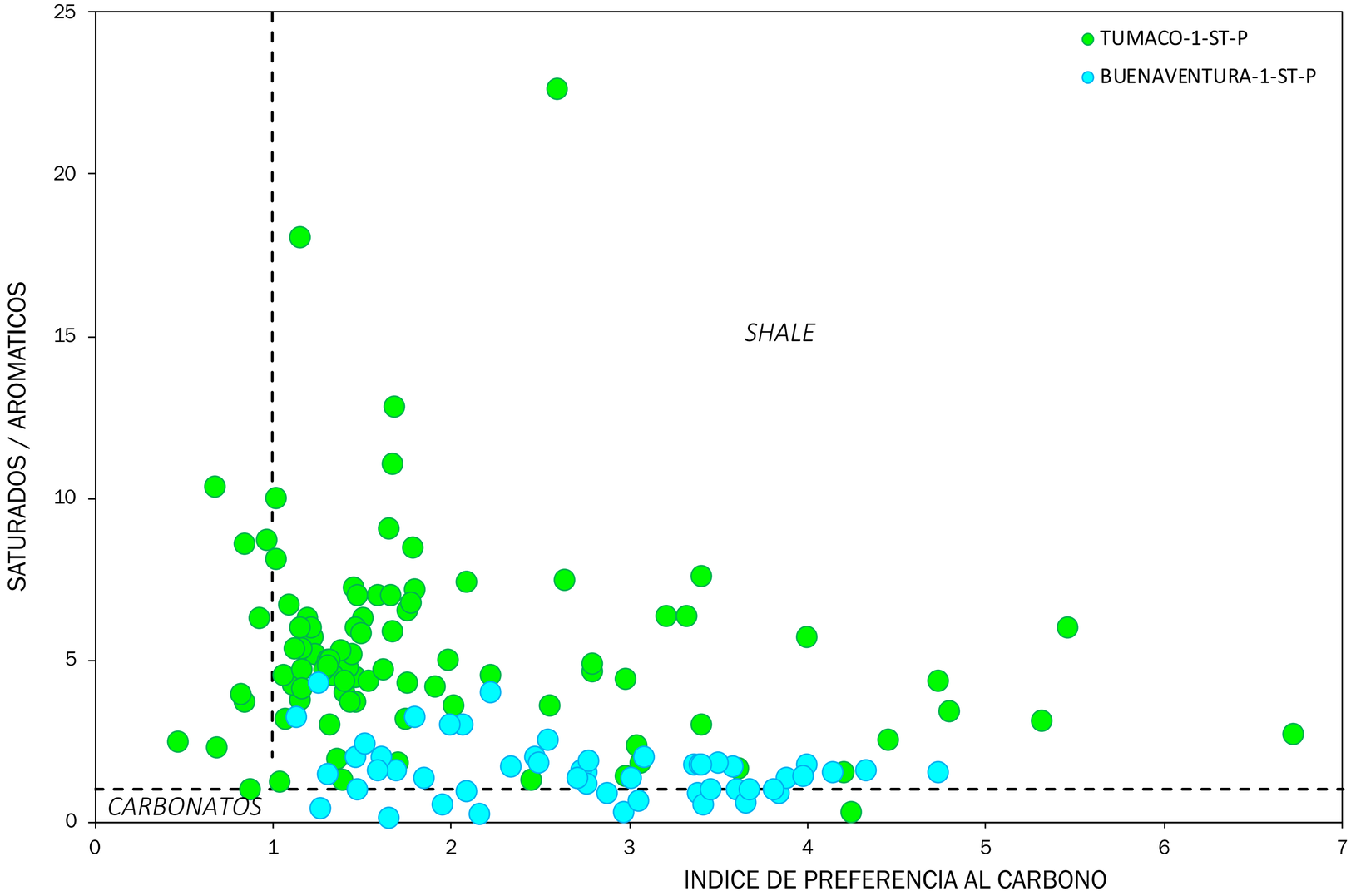
MAS & TAS OF THE BITUMINOUS EXTRACTS FROM TUMACO-1-ST-P WELL



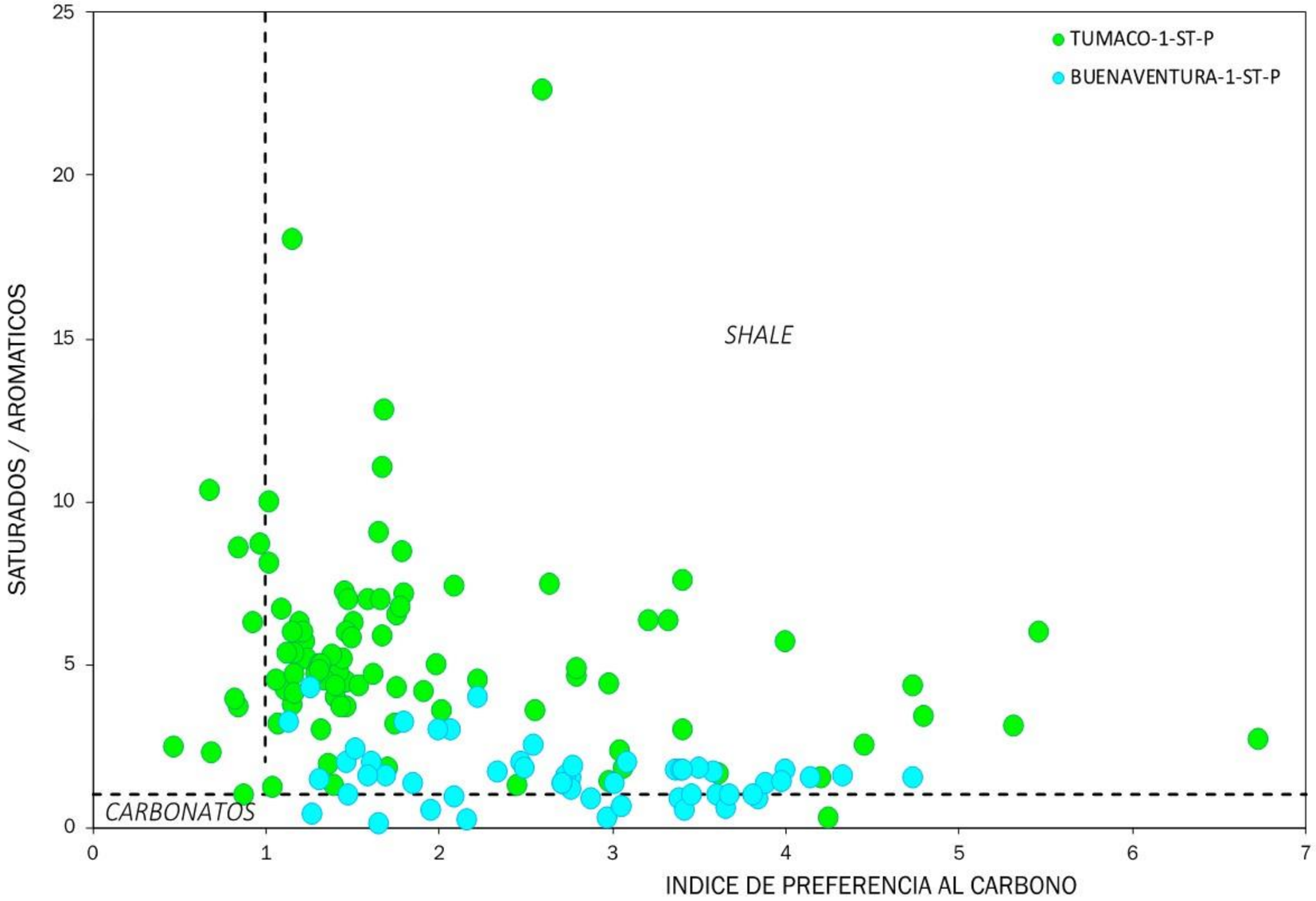
MAS & TAS OF THE BITUMINOUS EXTRACTS FROM B/VENTURA-1-ST-P WELLS



MAS & TAS OF THE BITUMINOUS EXTRACTS FROM B/VENTURA-1-ST-P WELLS



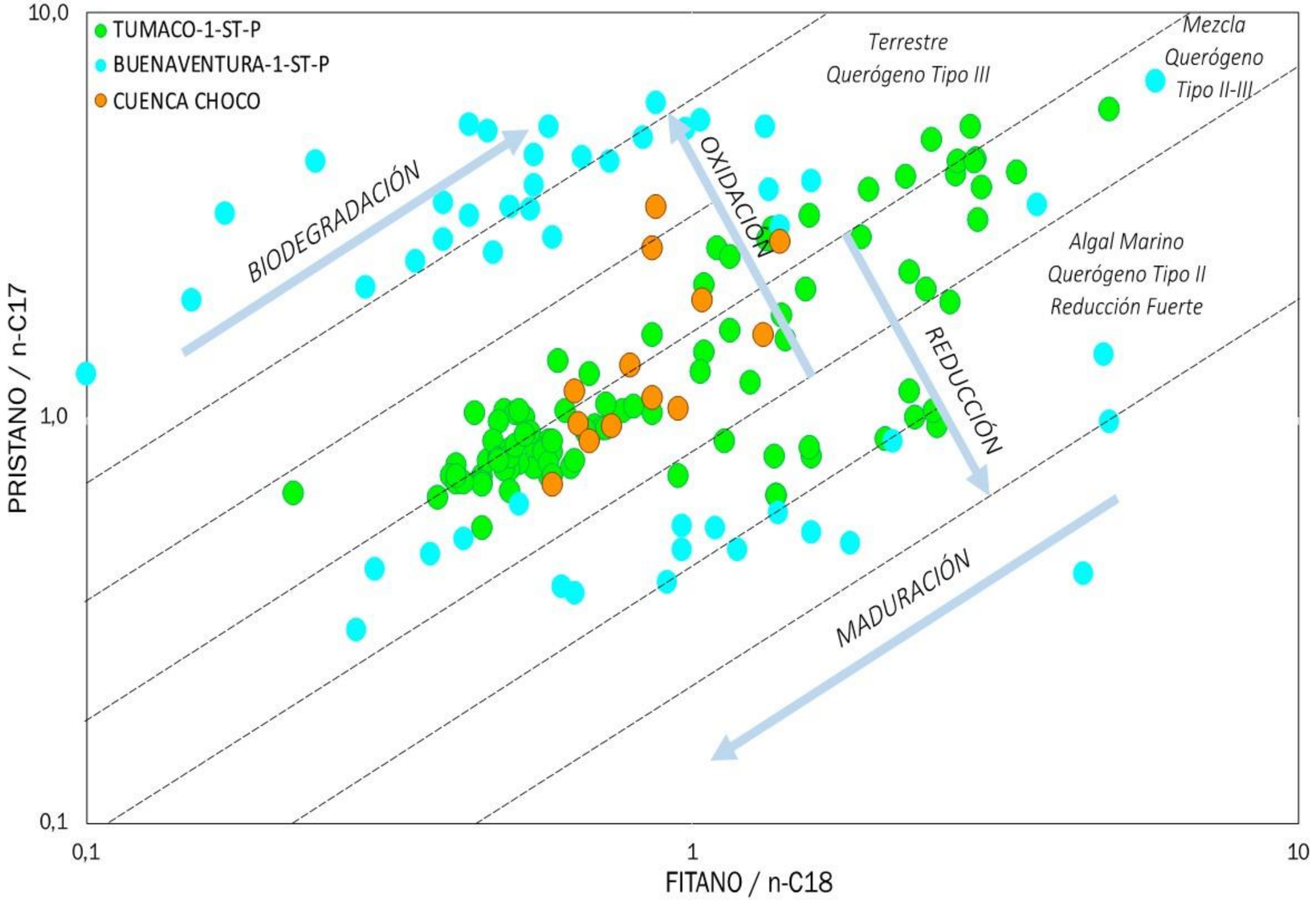
SATURATES/AROMATICS vs CARBON PREFERENCE INDEX (CPI)



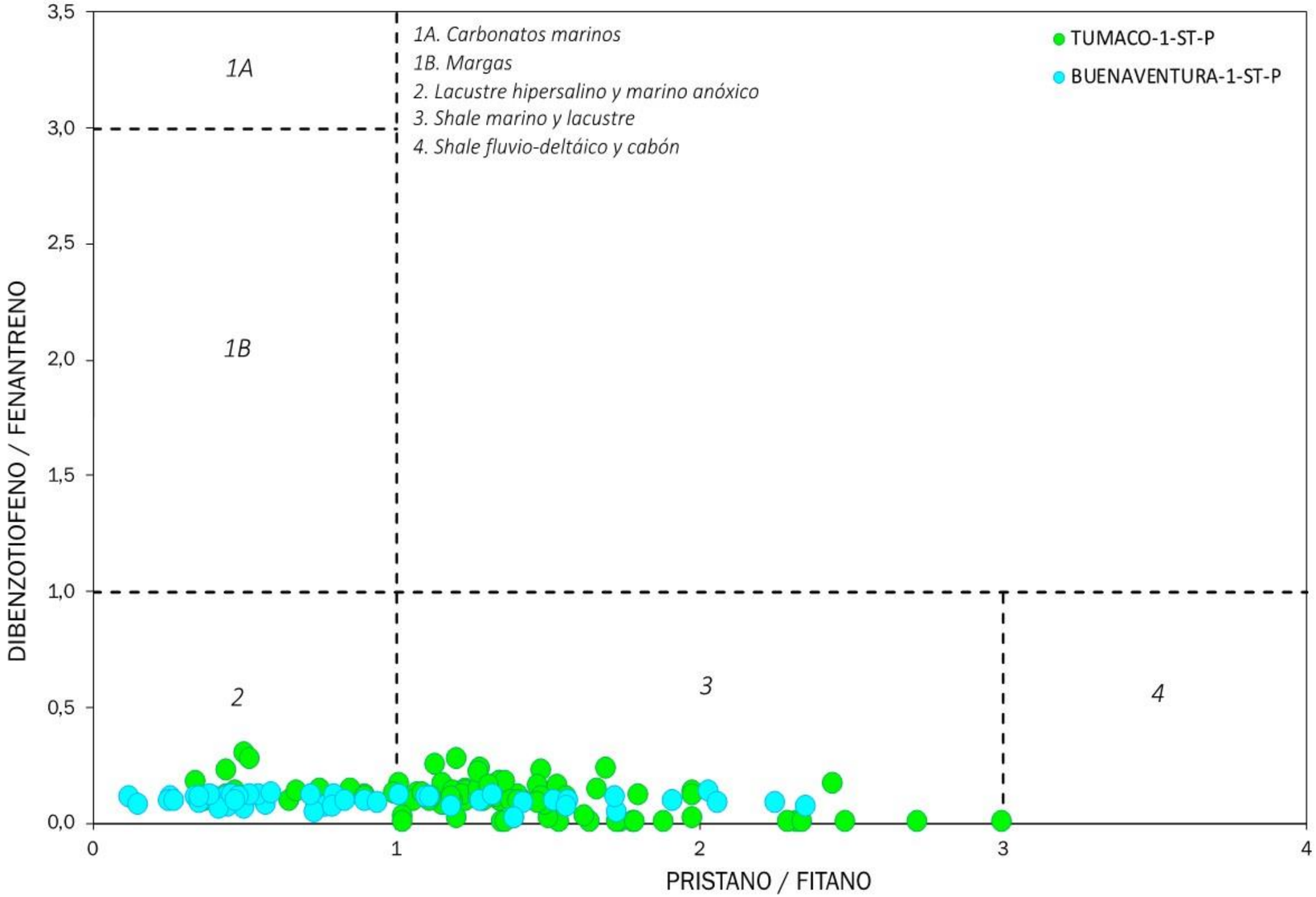
GEOCHEMICAL CORRELATIONS OF THE BITUMINOUS EXTRACTS FROM TUMACO & SAN JUAN/ATRATO BASINS

ORIGIN & DEPOSITIONAL ENVIRONMENTS

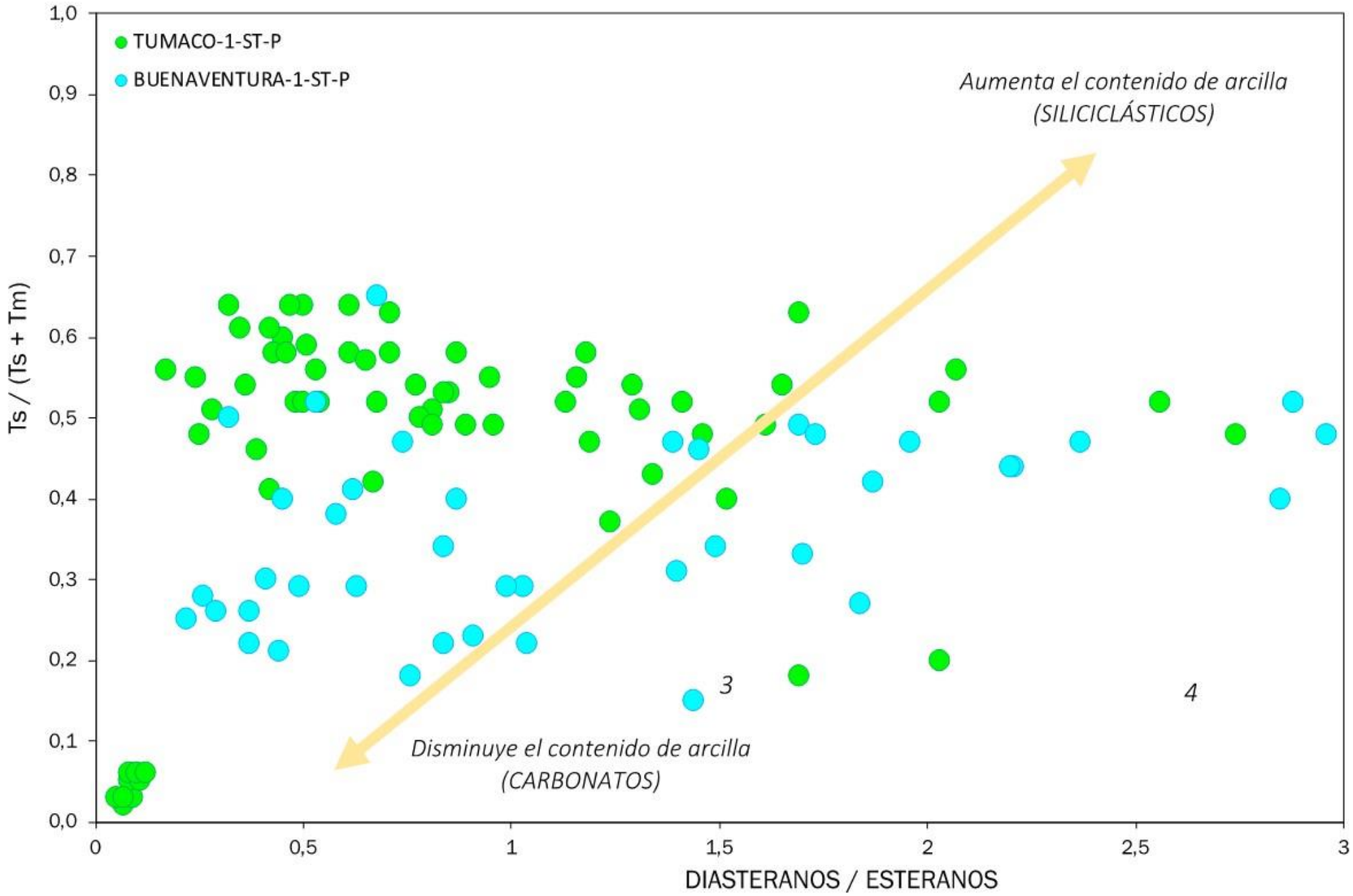
ISOPRENOIDS/N-ALKANES SHOWING O.M. ORIGIN & DEPOSITIONAL ENVIRONMENT IN THE TUMACO & SAN JUAN-ATRATO BASINS



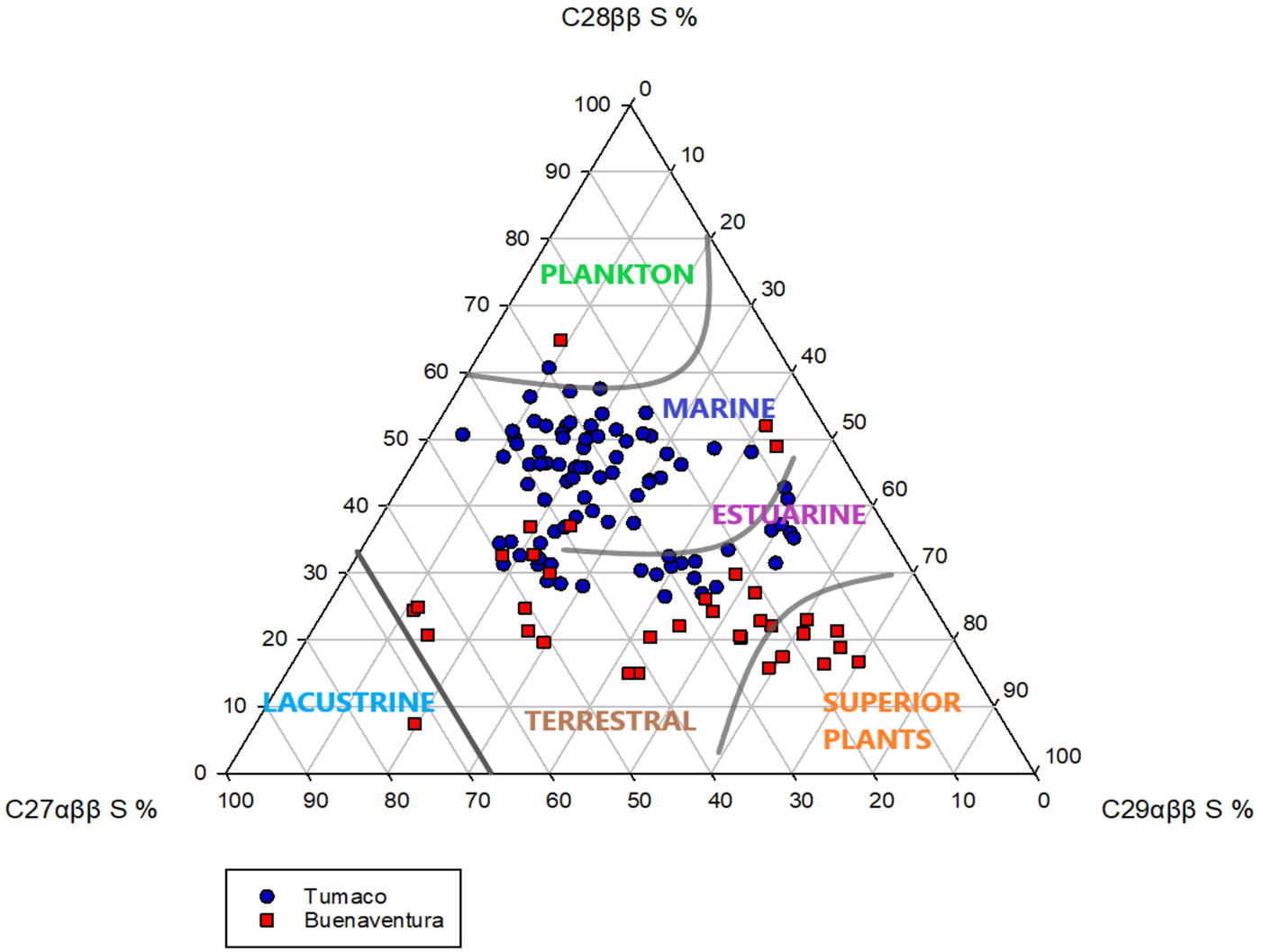
DBT/PHEN vs. Pr/Ph IN BITUMINOUS EXTRACTS IN THE TUMACO BASIN



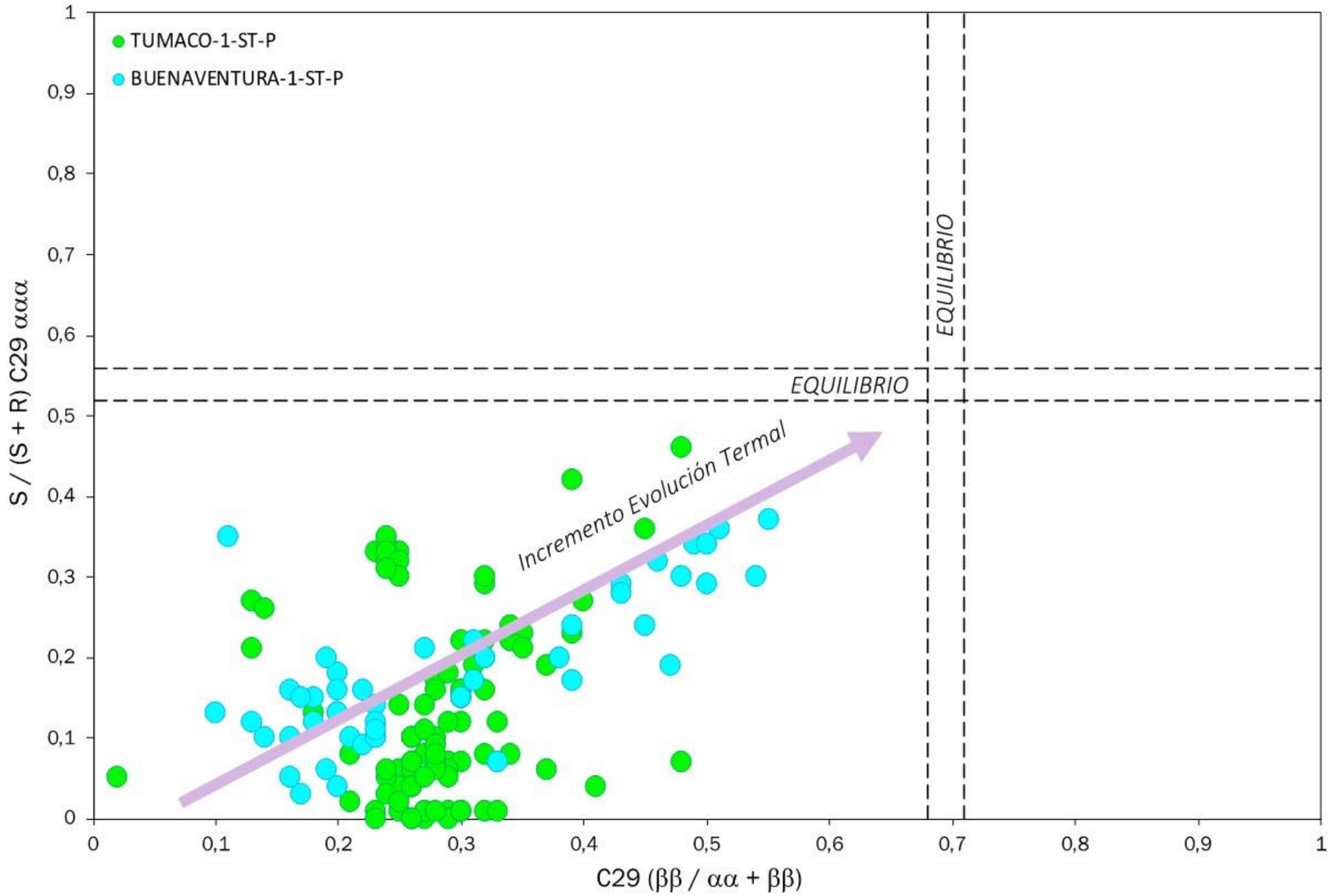
Ts/(Ts+Tm) vs. DIASTERANES/STERANES IN BITUMINOUS EXTRACTS IN THE TUMACO BASIN



TERNARY DIAGRAM SHOWING THE DEPOSITIONAL ENVIRONMENTS BASED ON C_{27}, C_{28} & C_{29}-STERANES IN TUMACO-1-SP



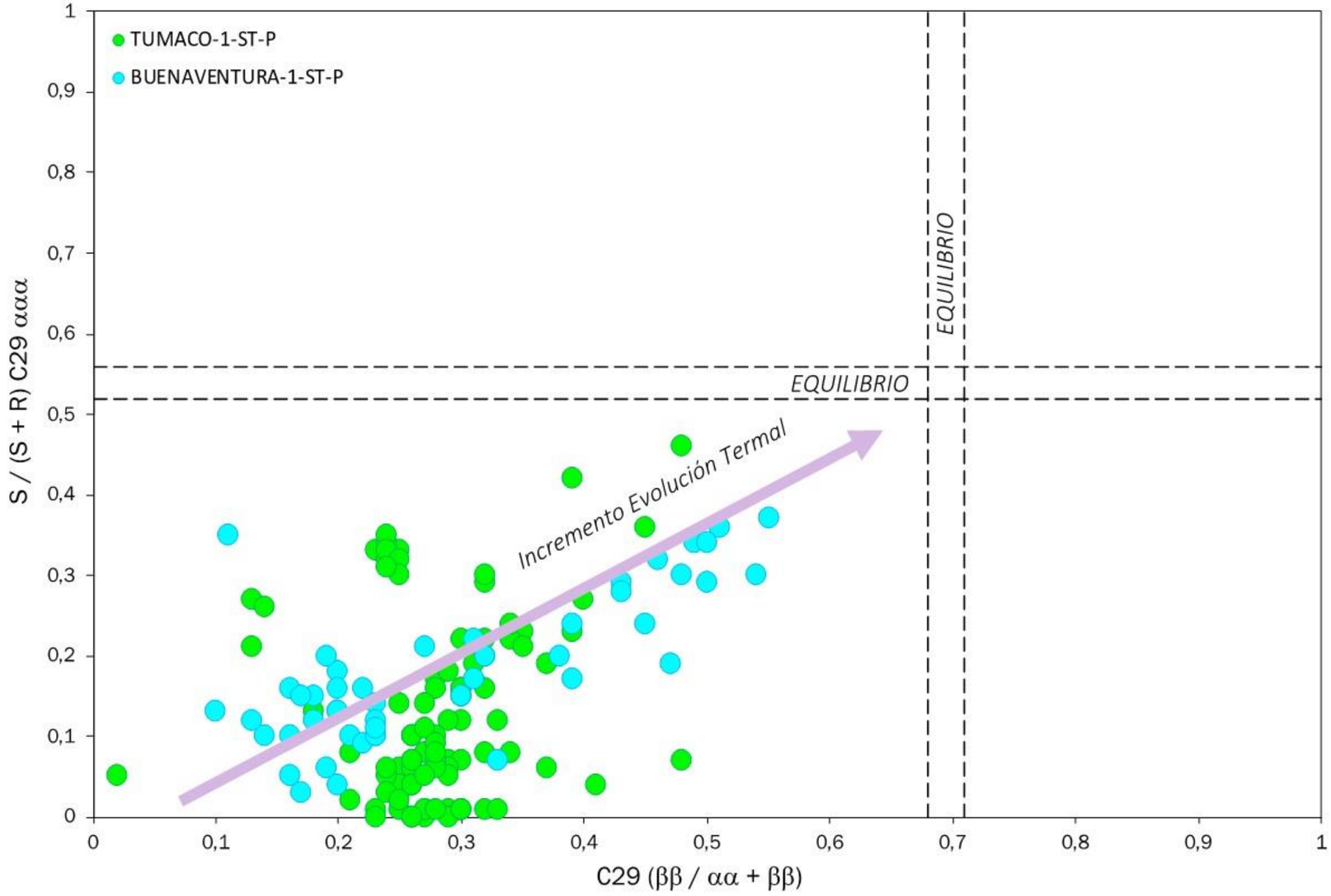
$C_{29}\alpha\alpha\alpha$ 20S/(20S+20R) vs. $C_{29}\beta\beta/\alpha\alpha+\beta\beta)$ IN TUMACO BASIN



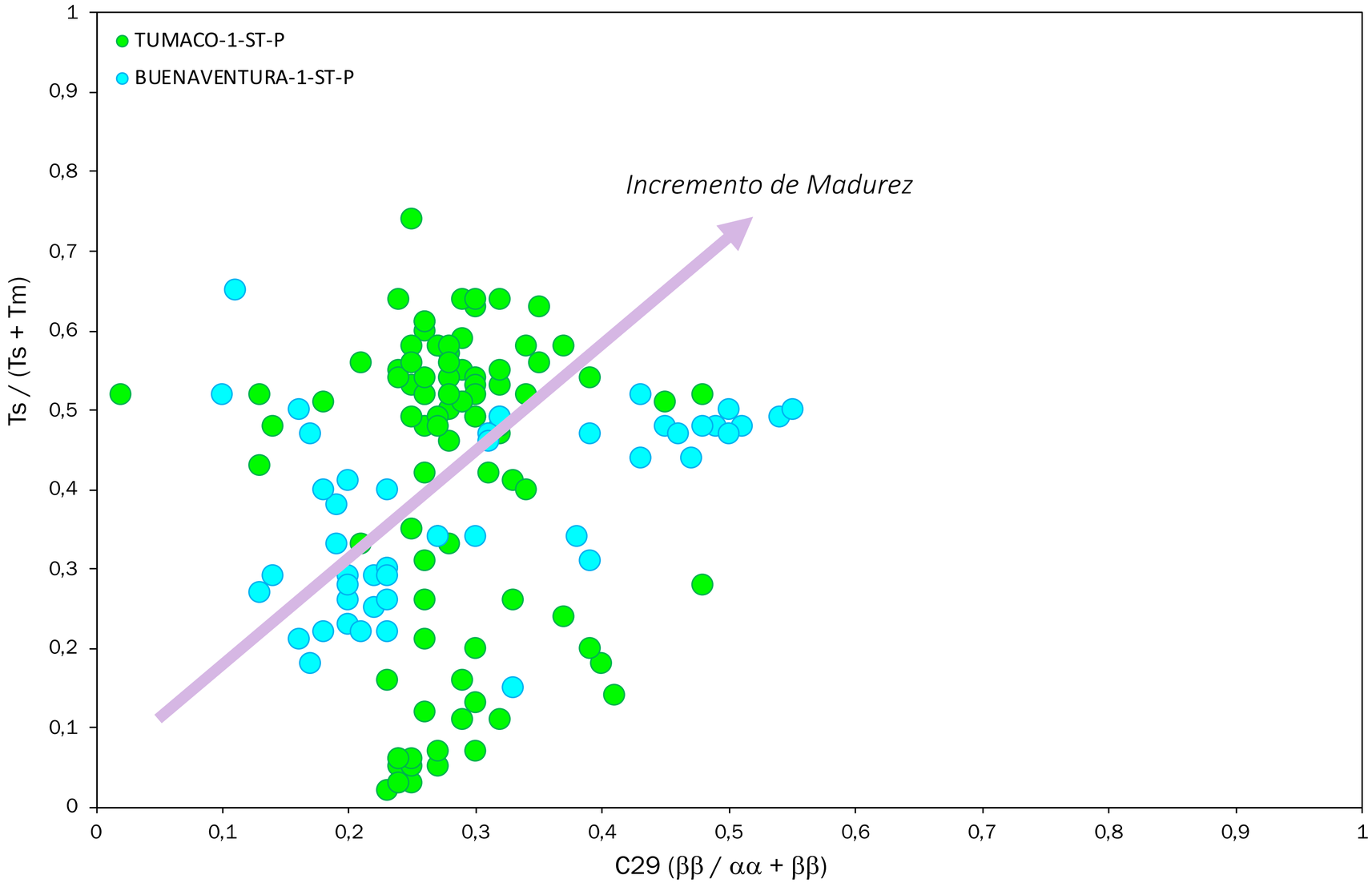
GEOCHEMICAL CORRELATIONS OF THE BITUMINOUS EXTRACTS FROM PACIFIC BASINS

THERMAL MATURITY

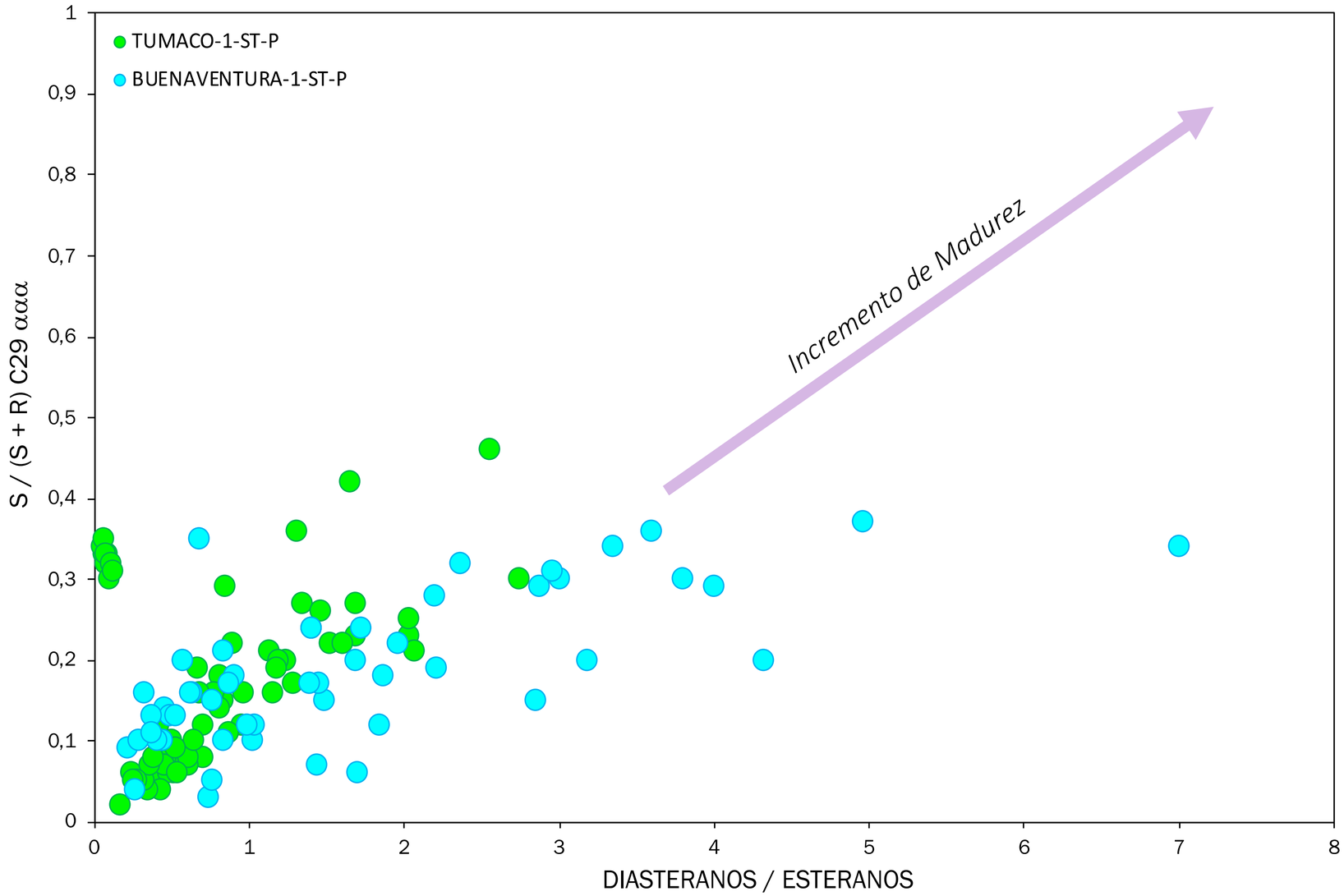
$C_{29}\alpha\alpha\alpha$ 20S/(20S+20R) vs. $C_{29}\beta\beta/\alpha\alpha+\beta\beta)$ IN TUMACO BASIN



Ts/(Ts+Tm) vs. $C_{29}\beta\beta/\alpha\alpha+\beta\beta$ IN TUMACO BASIN



$C_{29}\alpha\alpha\alpha$ 20S/(20S+20R) vs. DIASTERENES/STERANES IN TUMACO BASIN



6. Petroleum systems, prospectivity and yet to find

By Roberto Aguilera

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PETROLEUM SYSTEMS TUMACO BASIN

Source rocks

- **Cretaceous shales (Western Cordillera, Remolino Grande High and Gorgona Archipelago).**
- **Eocene shales and calcareous rocks (Western Cordillera and Borbon Basin – Ecuador).**

Reservoir rocks

- **Eocene sandstones and limestones (Western Cordillera).**
- **Middle and Late Miocene sandstones (Wells).**

Speculative Petroleum Systems (?) since there is only geological and/or geophysical evidence.

The existing geochemical data do not allow to determine with confidence, quality and maturity of the source rocks. However, the presence of several oil and gas seeps, and oil shows, indicate generation and migration of hydrocarbons in the basin.

Oil shows

Well	Depth feet	Show
Chagui-1	4319-4326	Mud gas cut
Chagui-1	6305-6311	Mud gas cut
Chagui-1	8792-8796	Mud gas cut
Remolino Grande-1	3141	Oil trace
Remolino Grande-1	3183	Oil trace
Remolino Grande-1	3257	Oil trace
Remolino Grande-1	3285	Oil trace

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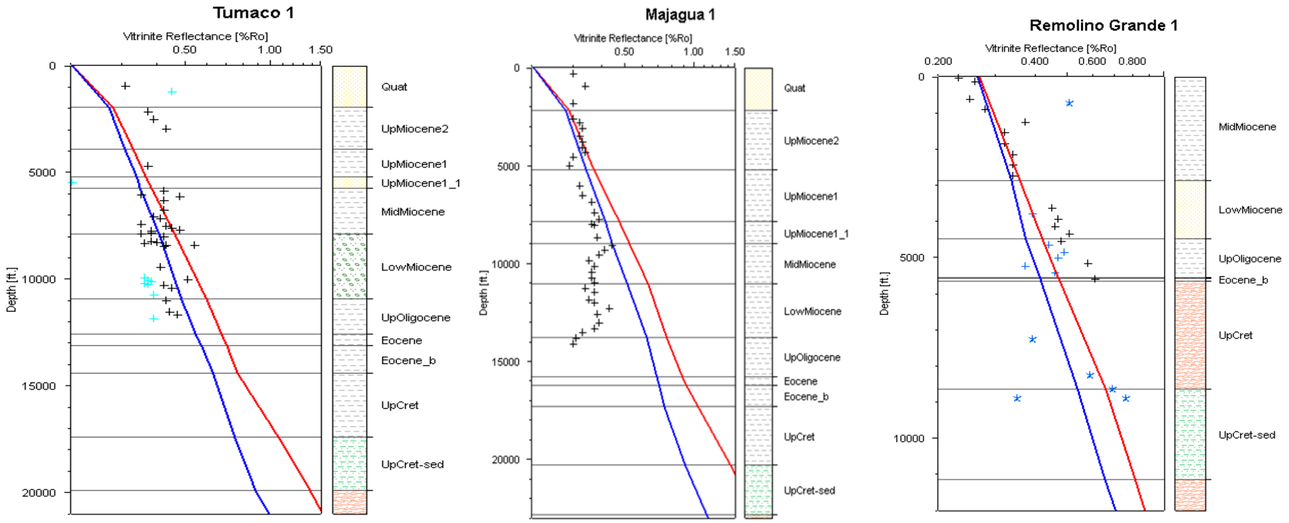
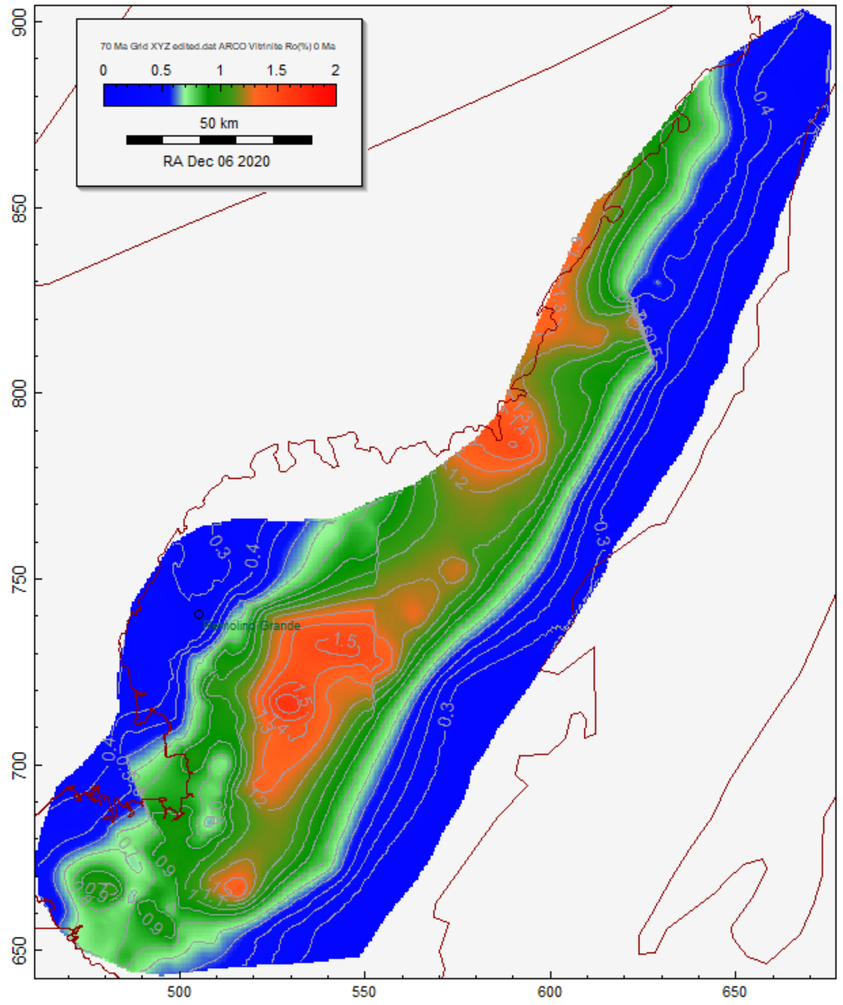
PETROLEUM SYSTEMS
TUMACO BASIN - BASIN MODELING



Basin modeling suggests that at the deepest part of the basin the potential source rocks could reach thermal maturity conditions to generate and expel hydrocarbons (oil and gas) – Type II and III Kerogens.

Vitrinite Reflectance (%Ro) – Upper Cretaceous



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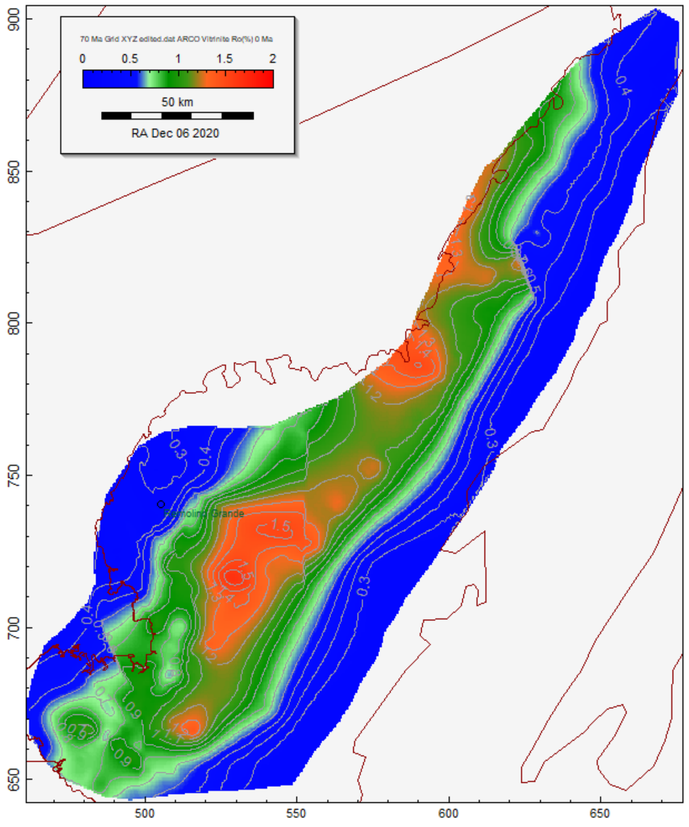
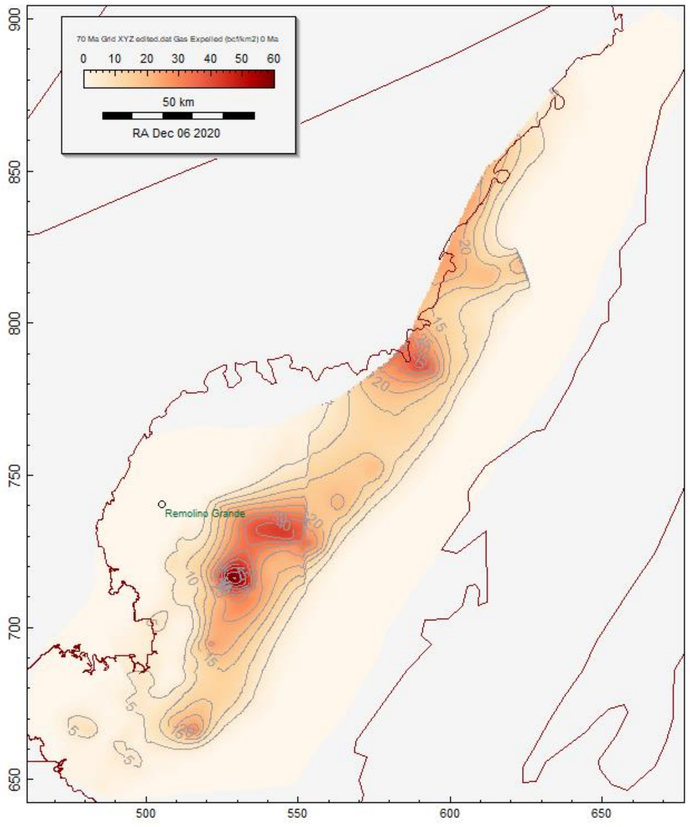
PETROLEUM SYSTEMS
TUMACO BASIN - BASIN MODELING

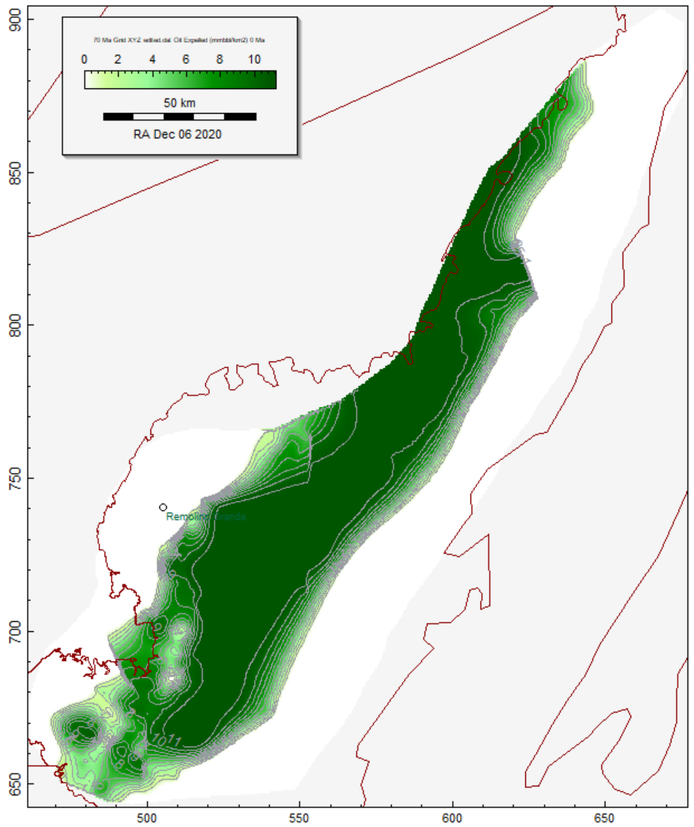
Vitrinite Reflectance



Gas Expelled



Oil Expelled



Upper Cretaceous – Present Day

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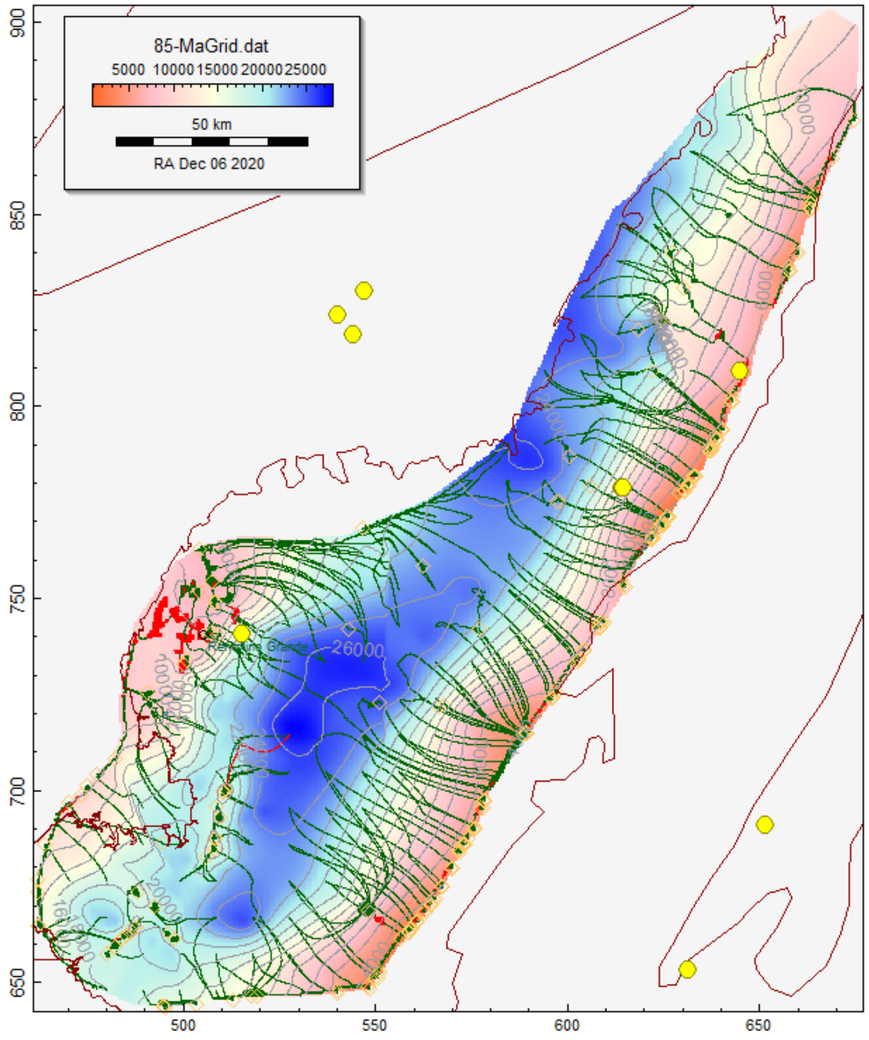
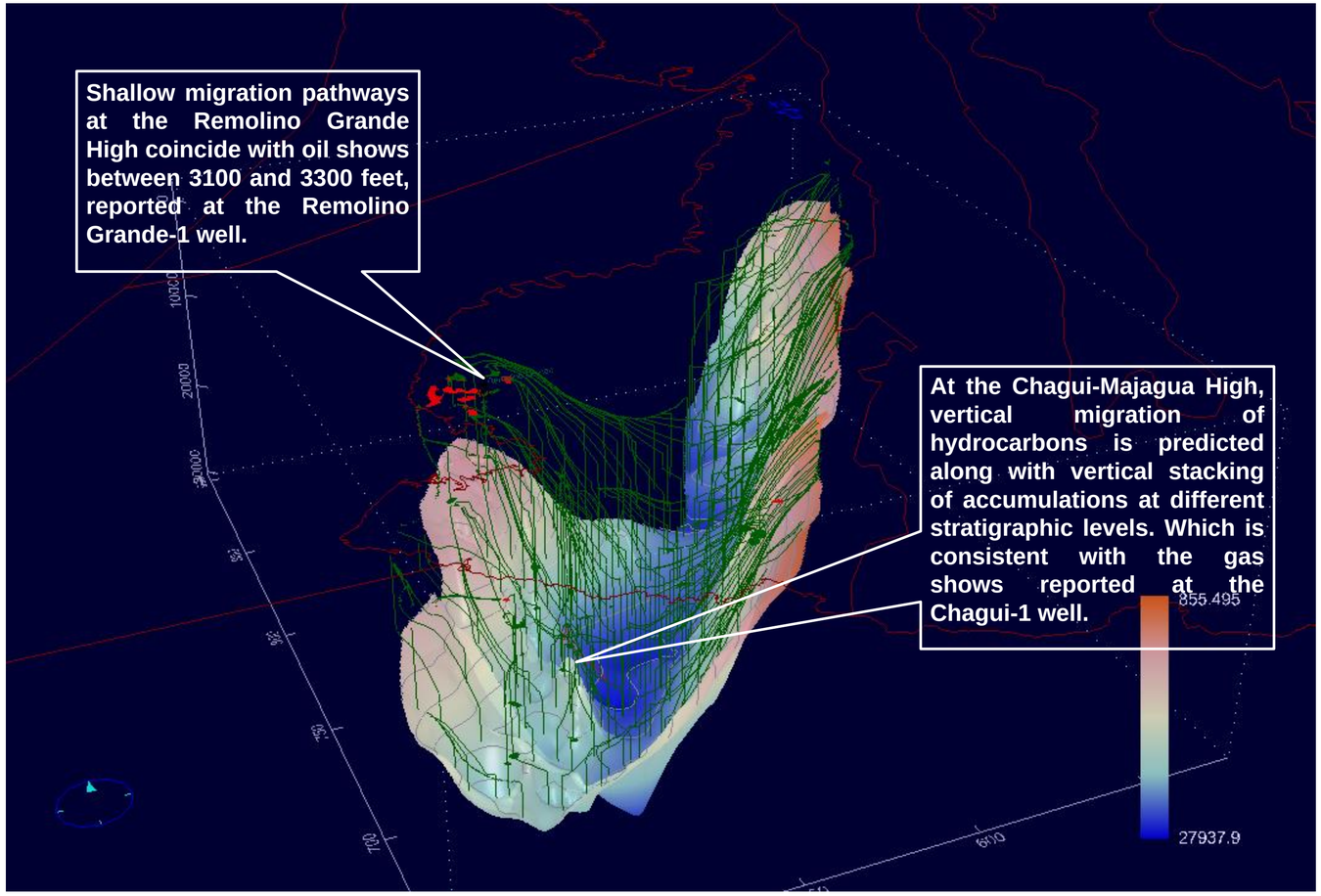
PETROLEUM SYSTEMS
TUMACO BASIN - BASIN MODELING



3D Modeling



Yellow dots - seeps

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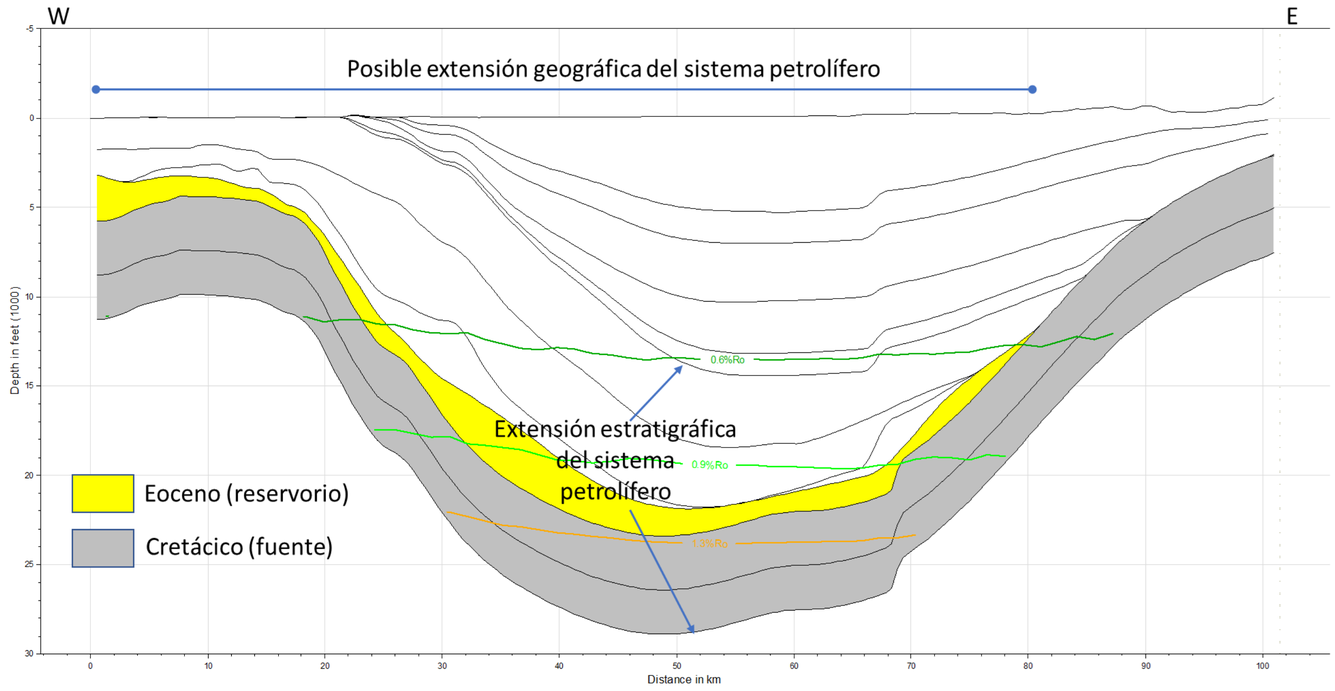
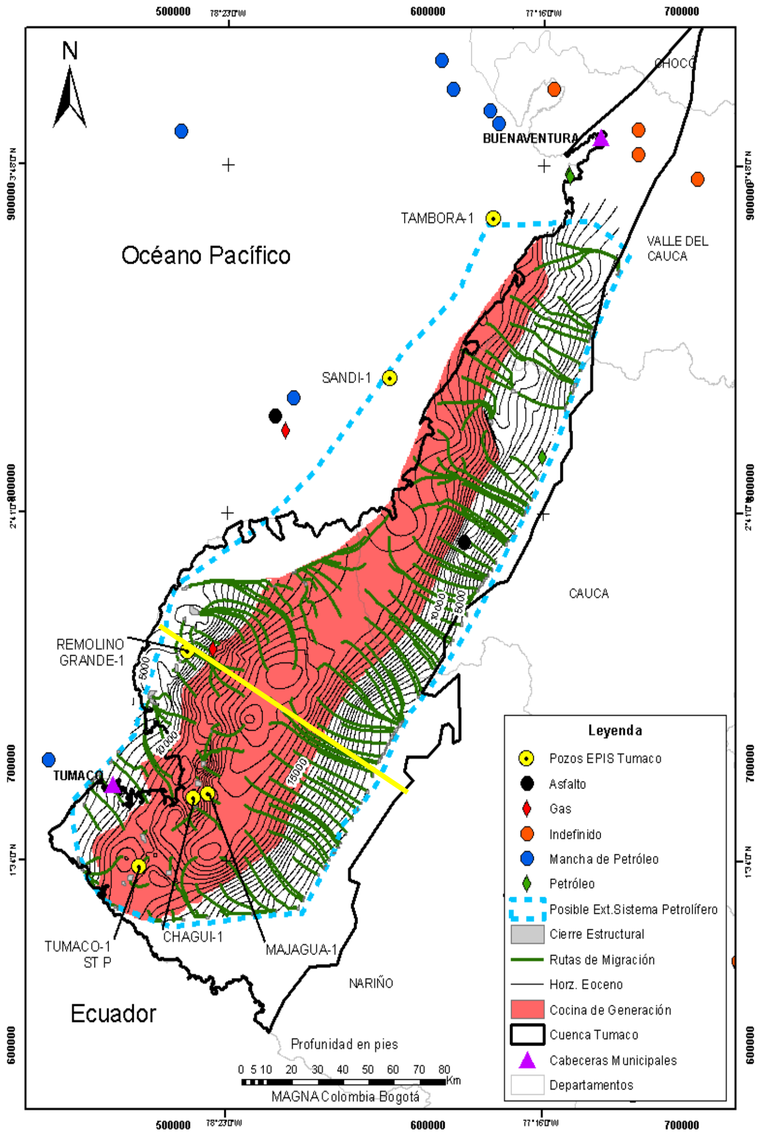
PETROLEUM SYSTEMS
TUMACO BASIN
Cretaceous – Eocene (?)

Stratigraphic extent



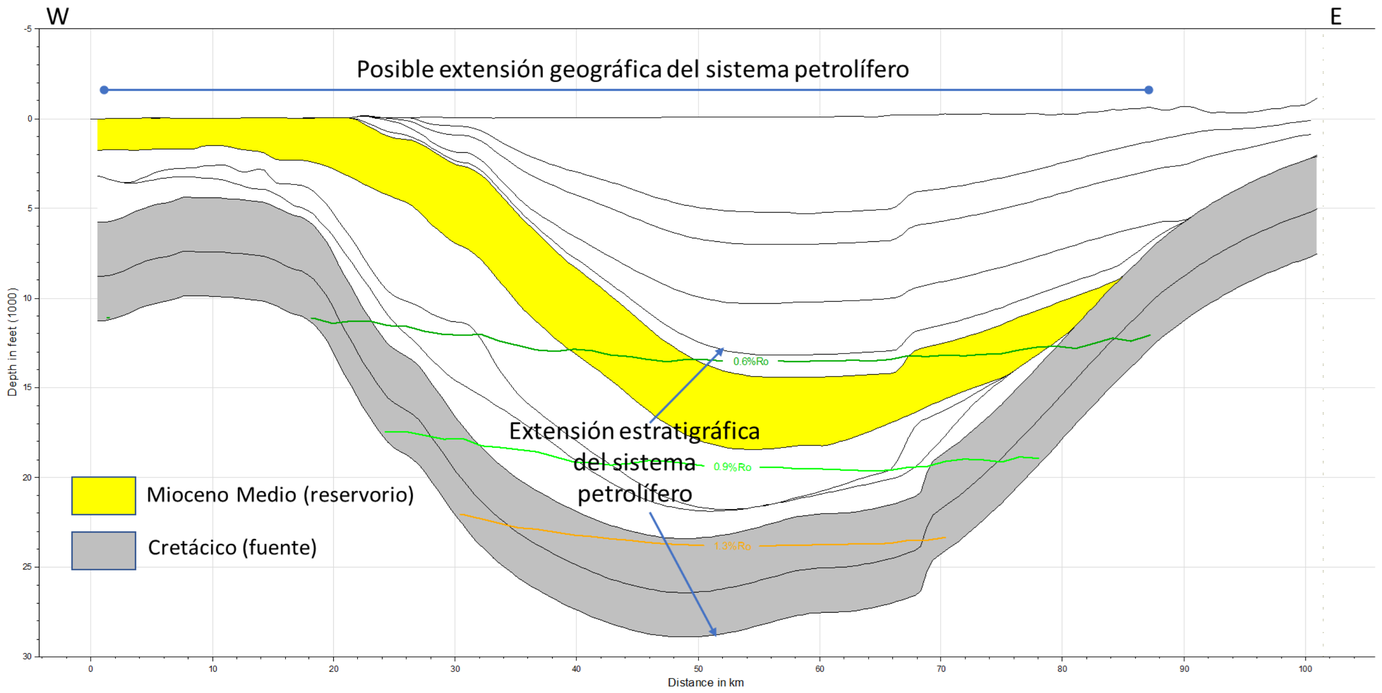
Geographical extent



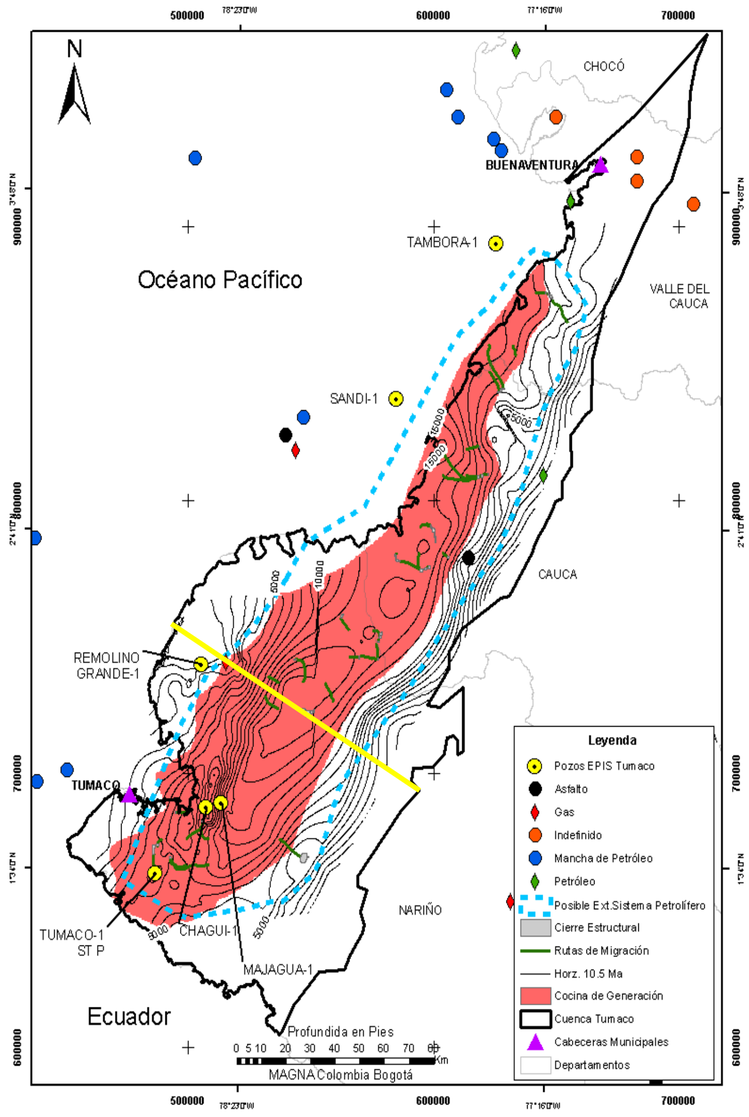
COLOMBIA ROUND 2021

PETROLEUM SYSTEMS
TUMACO BASIN
Cretaceous – Middle Miocene (?)

Stratigraphic extent



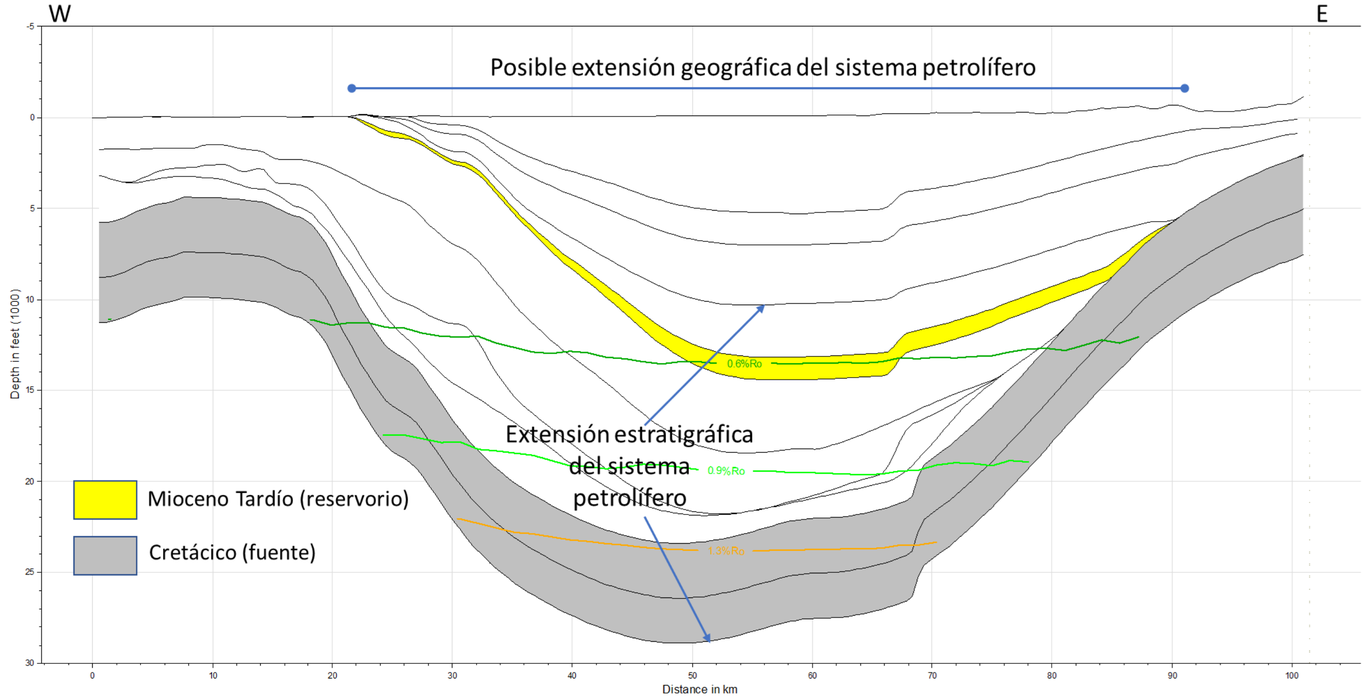
Geographical extent



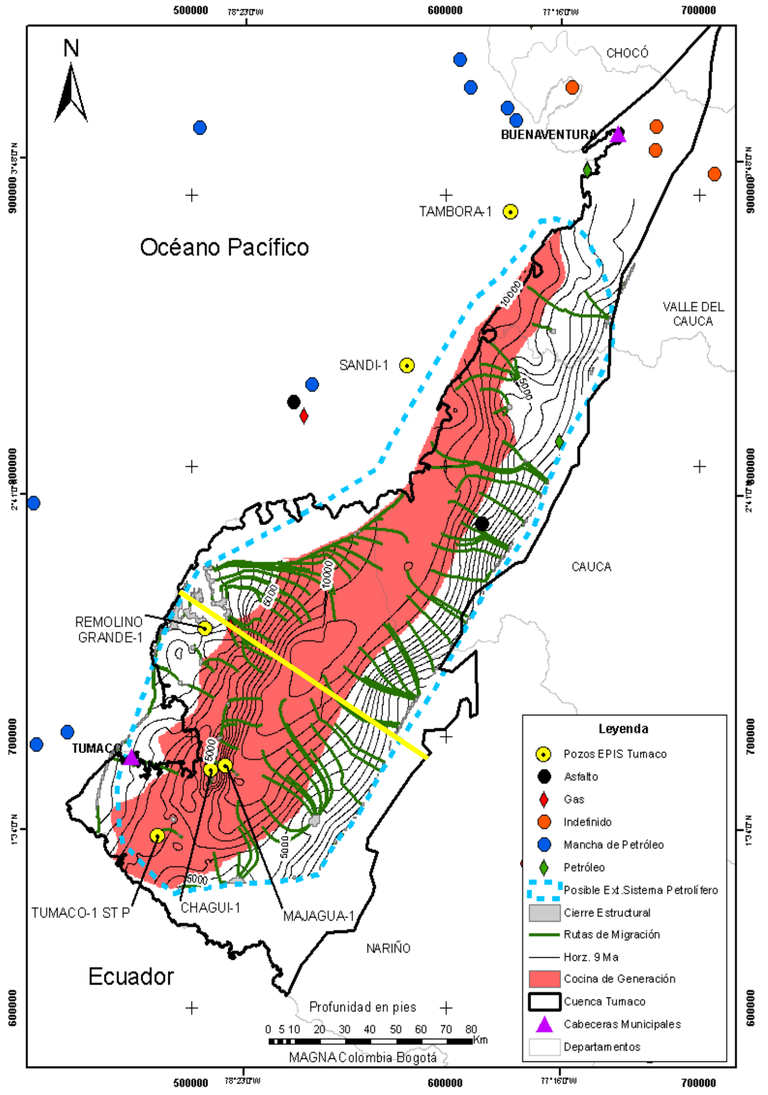
COLOMBIA ROUND 2021

PETROLEUM SYSTEMS
TUMACO BASIN
Cretaceous – Late Miocene (?)

Stratigraphic extent



Geographical extent



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PROSPECTIVITY TUMACO BASIN

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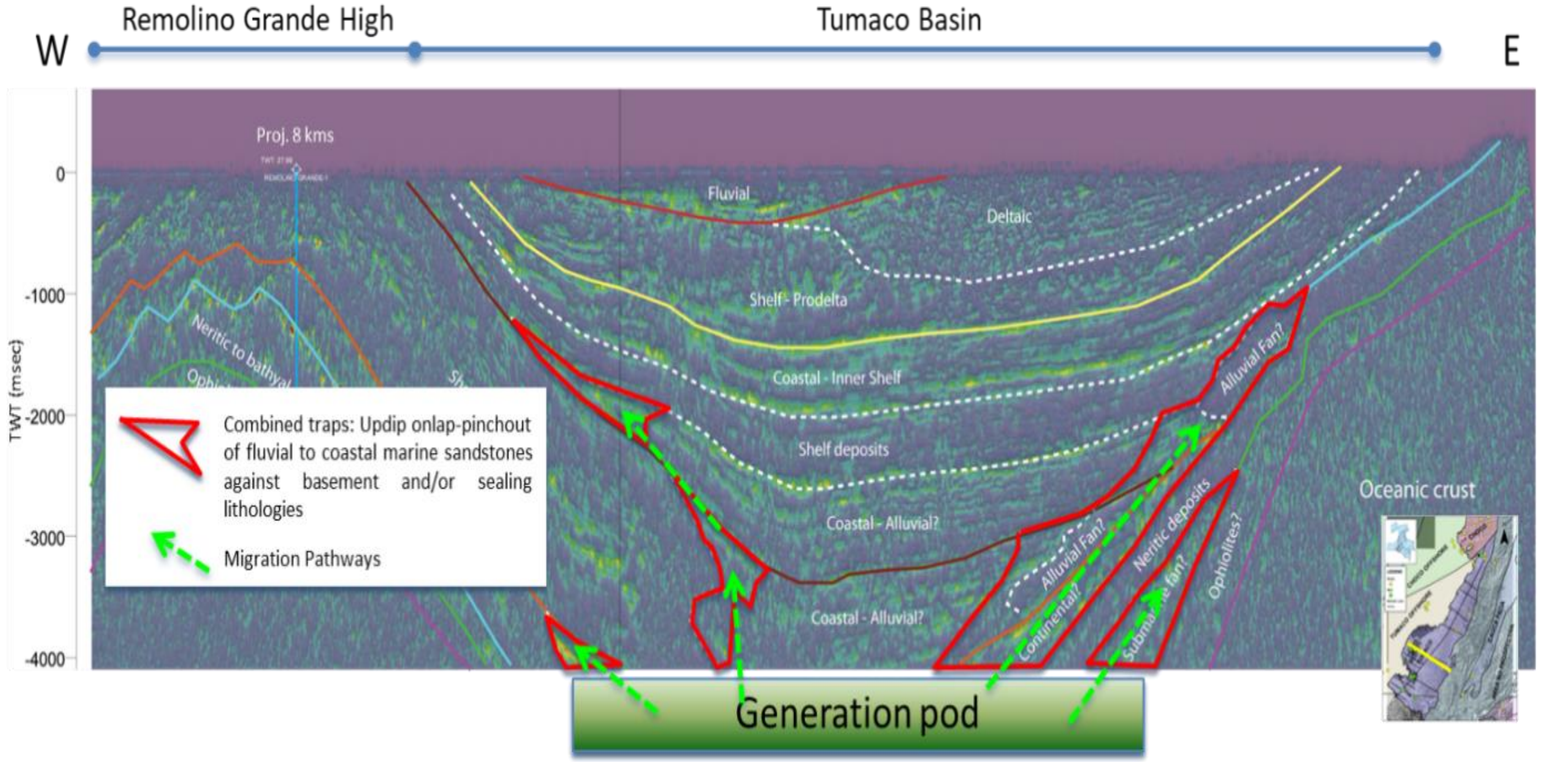
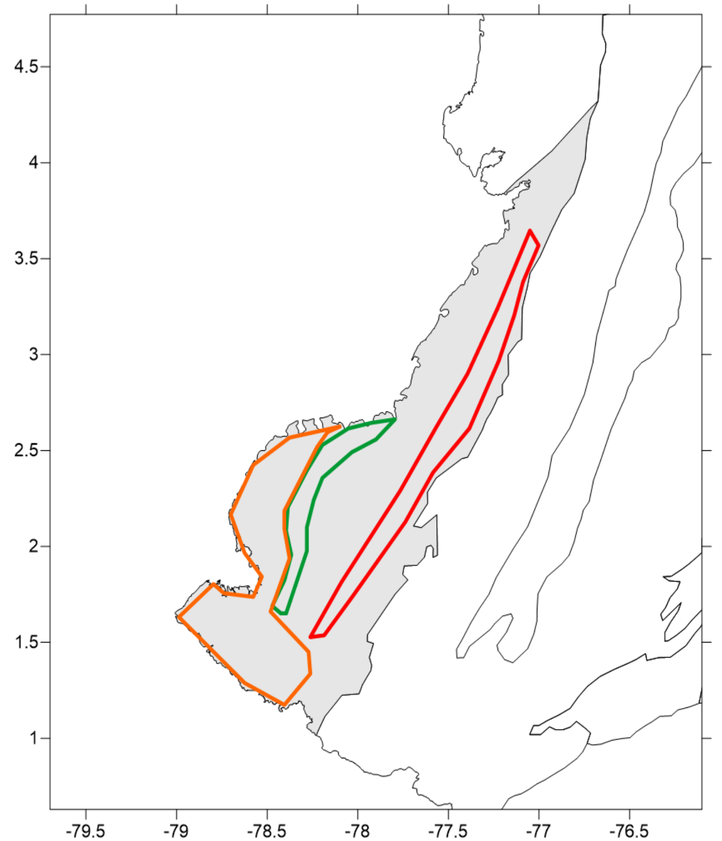
Play concepts



Aguilera, 2020

Areal extent



Plays por onlap/pinchamiento de sedimentos del Mioceno - Oligoceno contra sedimentos finos del Eoceno - Mioceno Temprano y/o rocas de basamento cretácico.

Plays por onlap/pinchamiento de sedimentos del Mioceno - Oligoceno contra sedimentos finos del Eoceno a Mioceno.

Play estructural por plegamiento de la cobertera sedimentaria en rocas del Oligoceno a Mioceno.

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PROSPECTIVITY TUMACO BASIN

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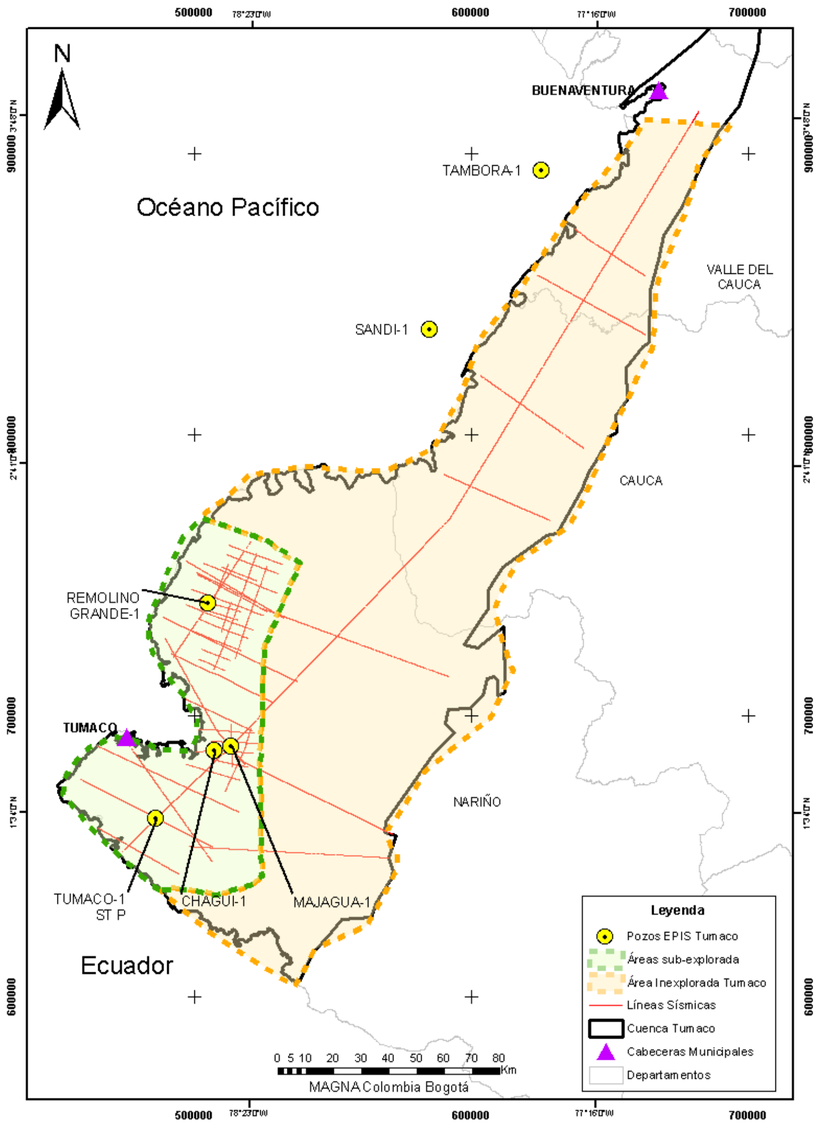
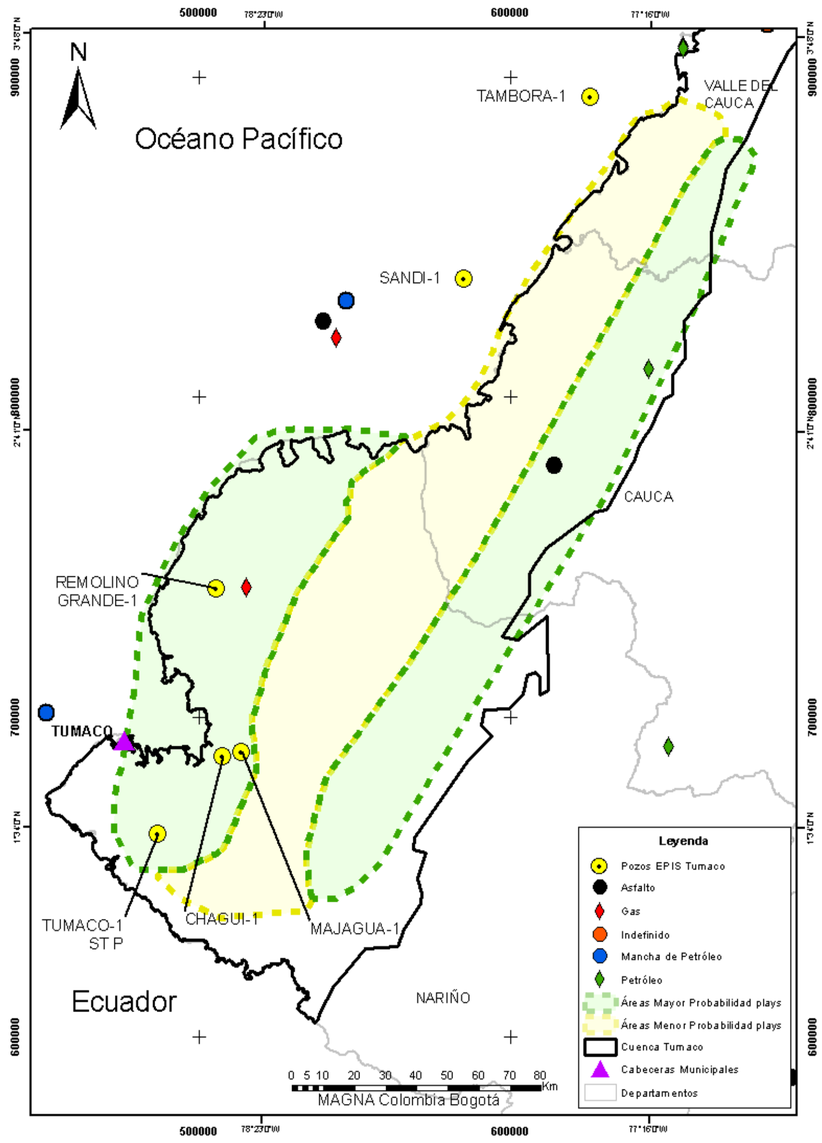
Underexplored areas



Exploratory corridors



YET TO FIND
TUMACO BASIN – PROSPECTIVE RESOURCES

Tumaco

Pepper & Corvi (1995) - 3D	MBO	TCF
P_{10}	3801.5	32.8
P_{50}	1666.9	19.8
P_{90}	141.2	10.7

Pepper & Corvi (1995) - 1D	MBO	TCF
Promedio	1518.9	1.6

Schmoker (1994) - Hunt (1995)	MBO	TCF
P_{10}	1844.3	7.2
P_{50}	1040.0	3.4
P_{90}	239.1	0.6

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PETROLEUM SYSTEMS SAN JUAN BASIN

Source rocks

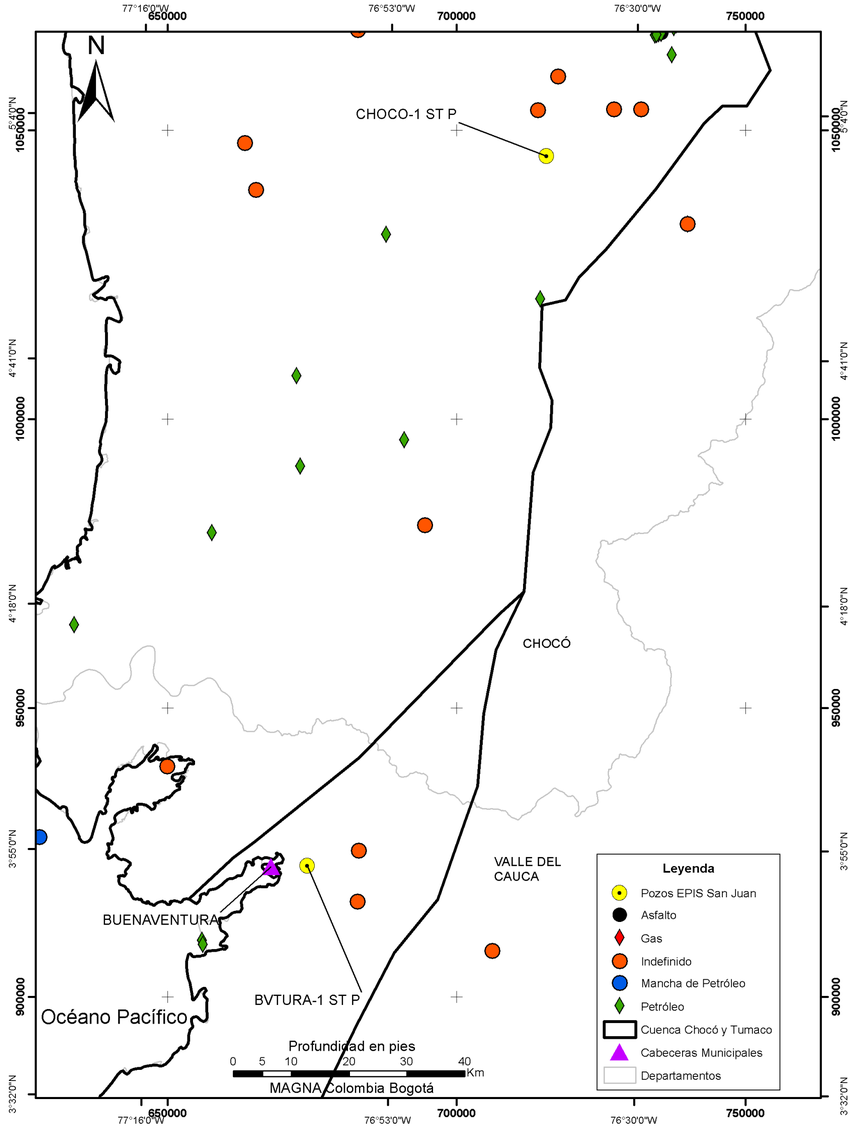
- **Cretaceous shales (Western Cordillera, and Gorgona Archipelago).**
- **Eocene - Oligocene shales and calcareous rocks (Western Cordillera, and Itsmina – Condoto High).**

Reservoir rocks

- **Eocene - Oligocene sandstones and limestones (Western Cordillera, and Itsmina – Condoto High).**

Speculative Petroleum Systems (?) since there is only geological and/or geophysical evidence.

The existing geochemical data do not allow to determine with confidence, quality and maturity of the source rocks. However, the presence of several oil and gas seeps, indicate generation and migration of hydrocarbons in the basin.



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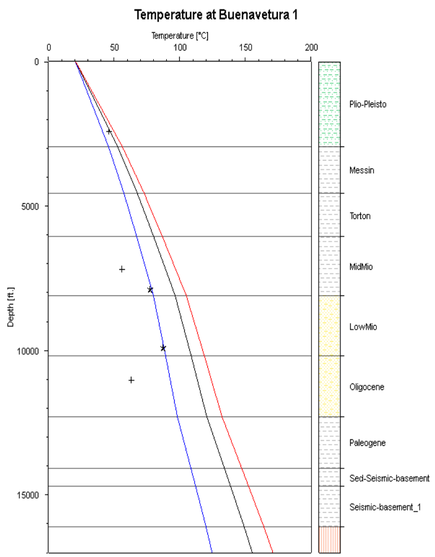
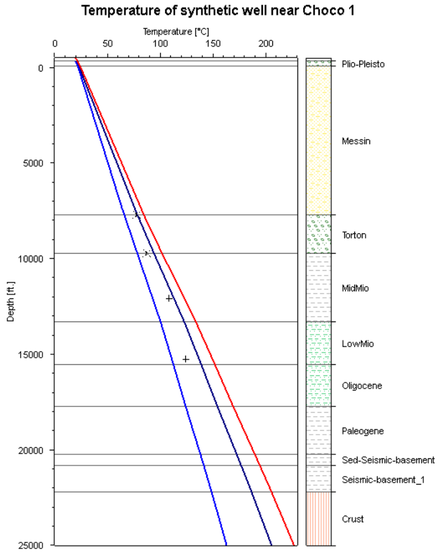
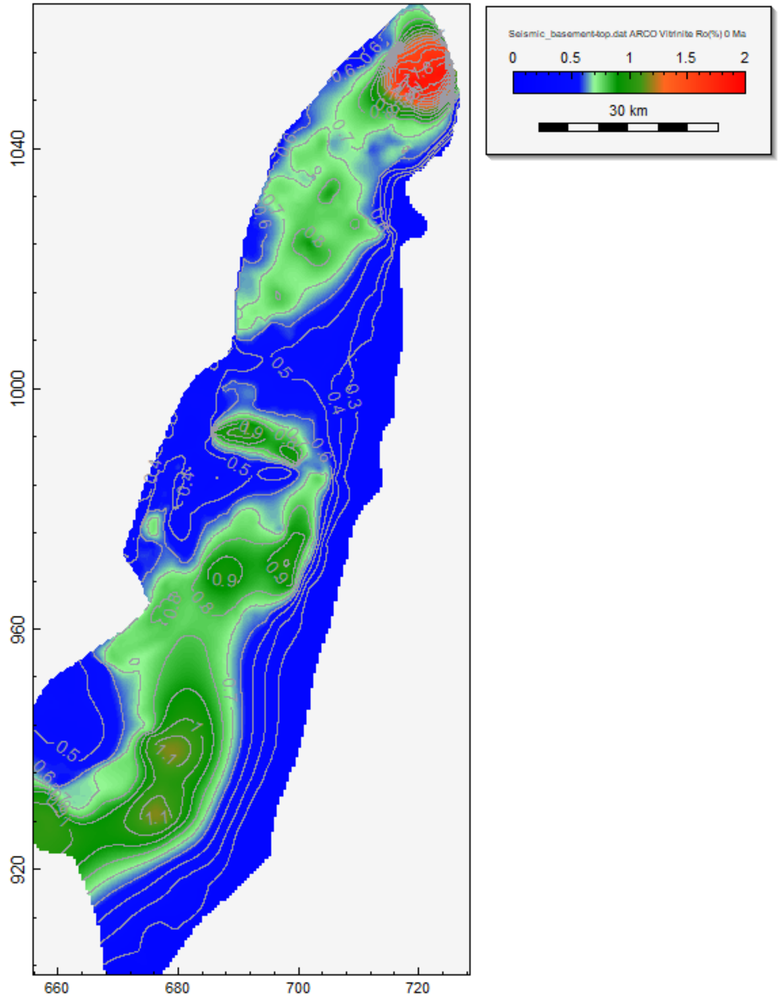
PETROLEUM SYSTEMS
SAN JUAN BASIN - BASIN MODELING





Basin modeling suggests that at the deepest part of the basin the potential source rocks could reach thermal maturity conditions to generate and expel hydrocarbons (oil and gas) – Type II and III Kerogens.

Vitrinite Reflectance (%Ro) – Upper Cretaceous



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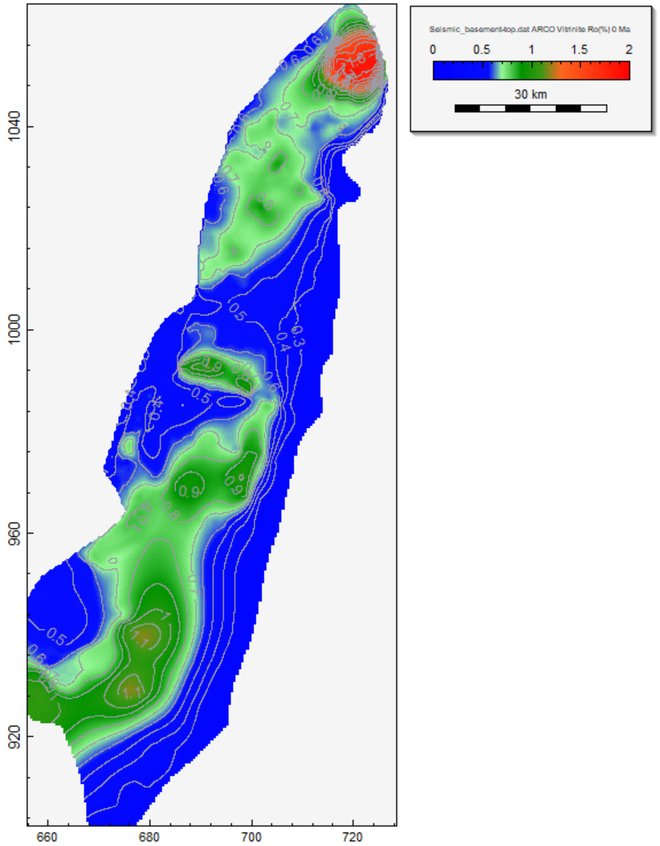
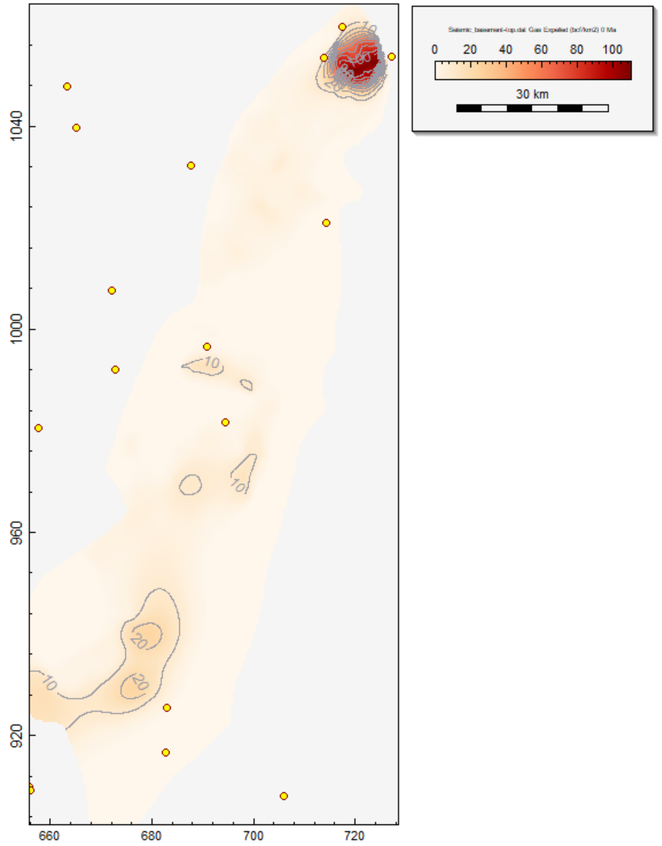
PETROLEUM SYSTEMS
SAN JUAN BASIN - BASIN MODELING

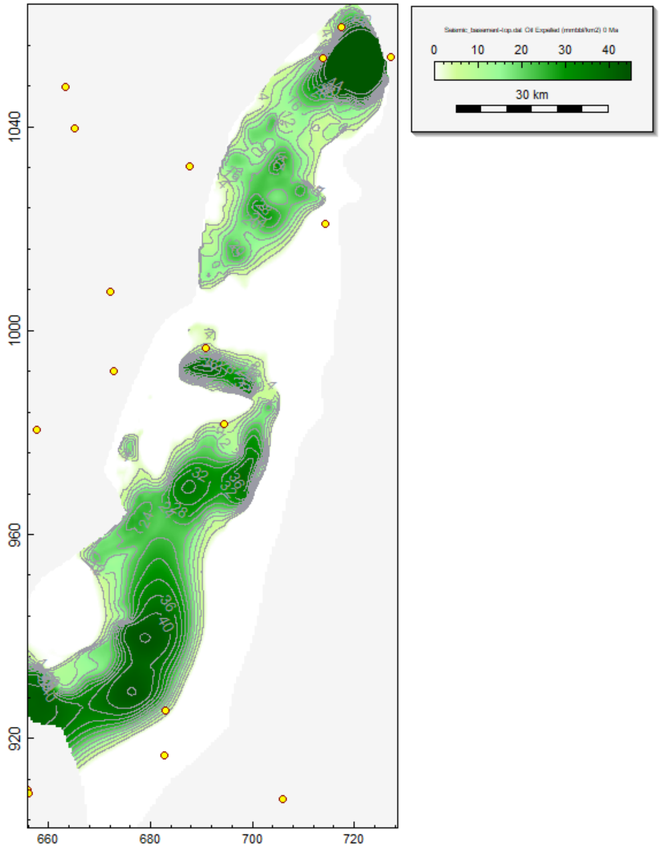
Vitrinite Reflectance



Gas Expelled



Oil Expelled



Upper Cretaceous – Present Day

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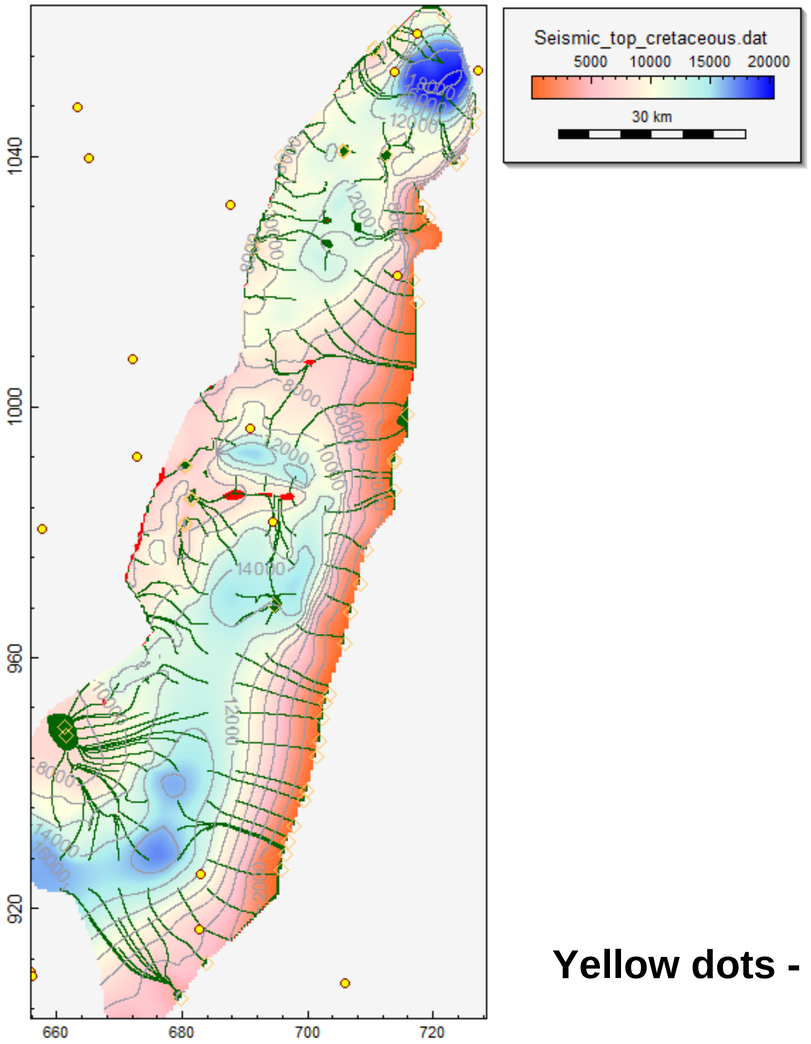
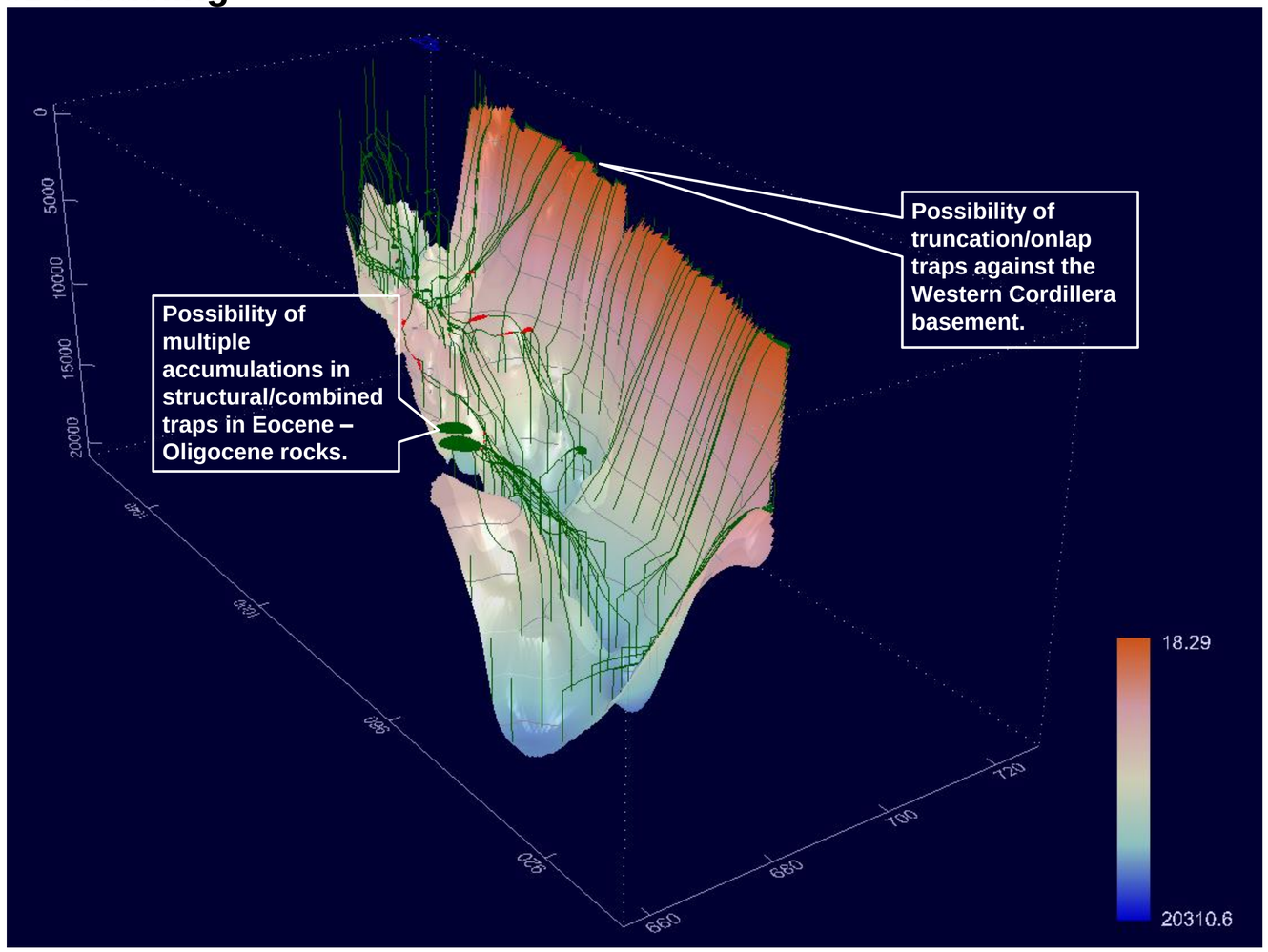
PETROLEUM SYSTEMS
SAN JUAN BASIN - BASIN MODELING



Yellow dots - seeps

3D Modeling



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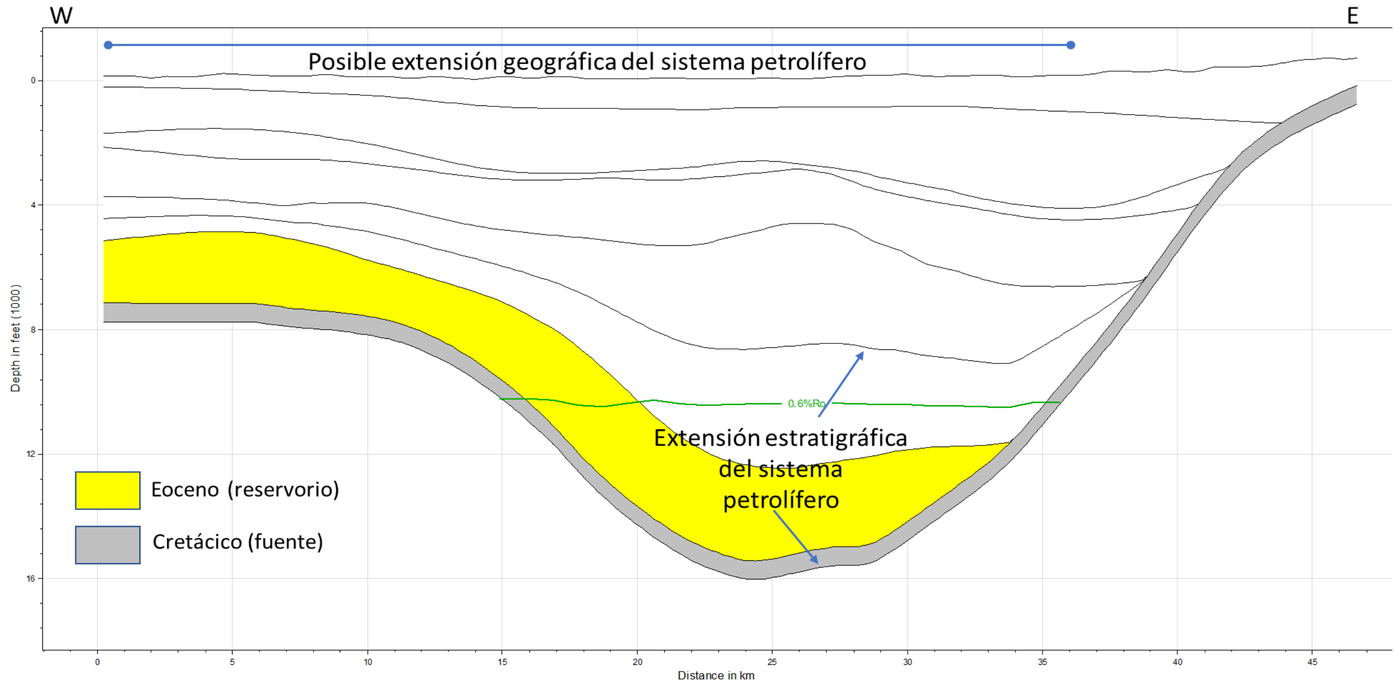
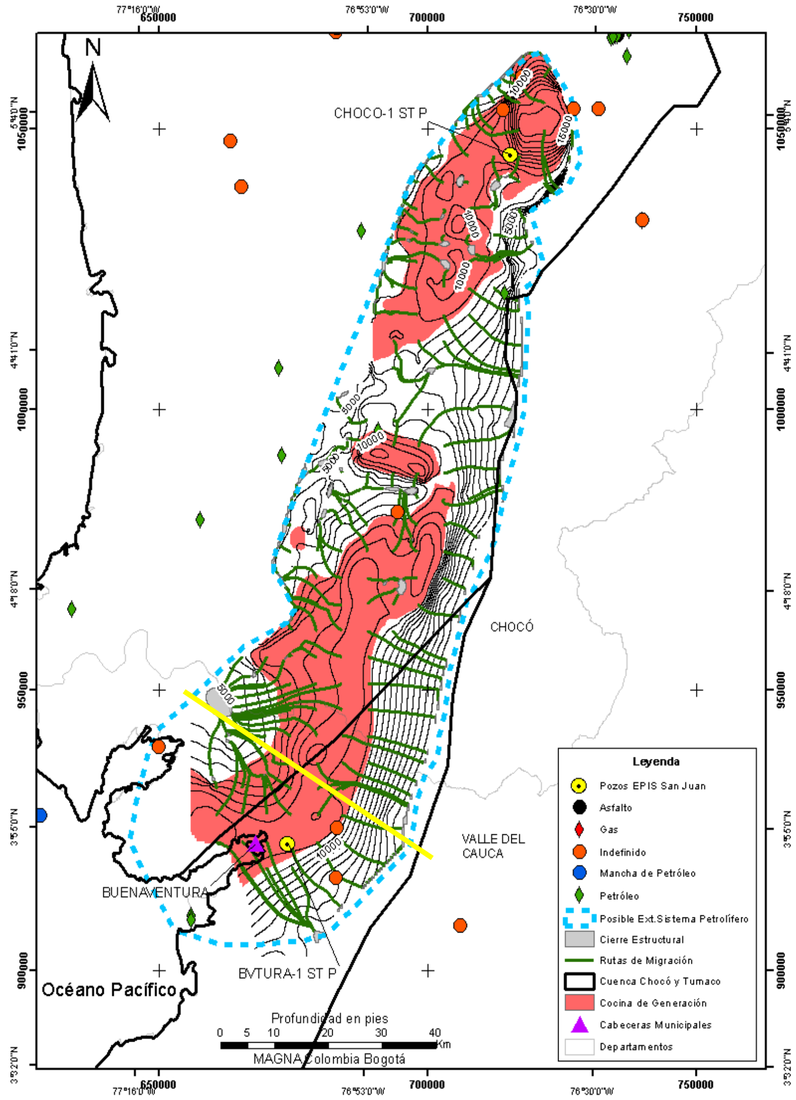
PETROLEUM SYSTEMS
SAN JUAN BASIN
Cretaceous – Eocene (?)

Stratigraphic extent



Geographical extent



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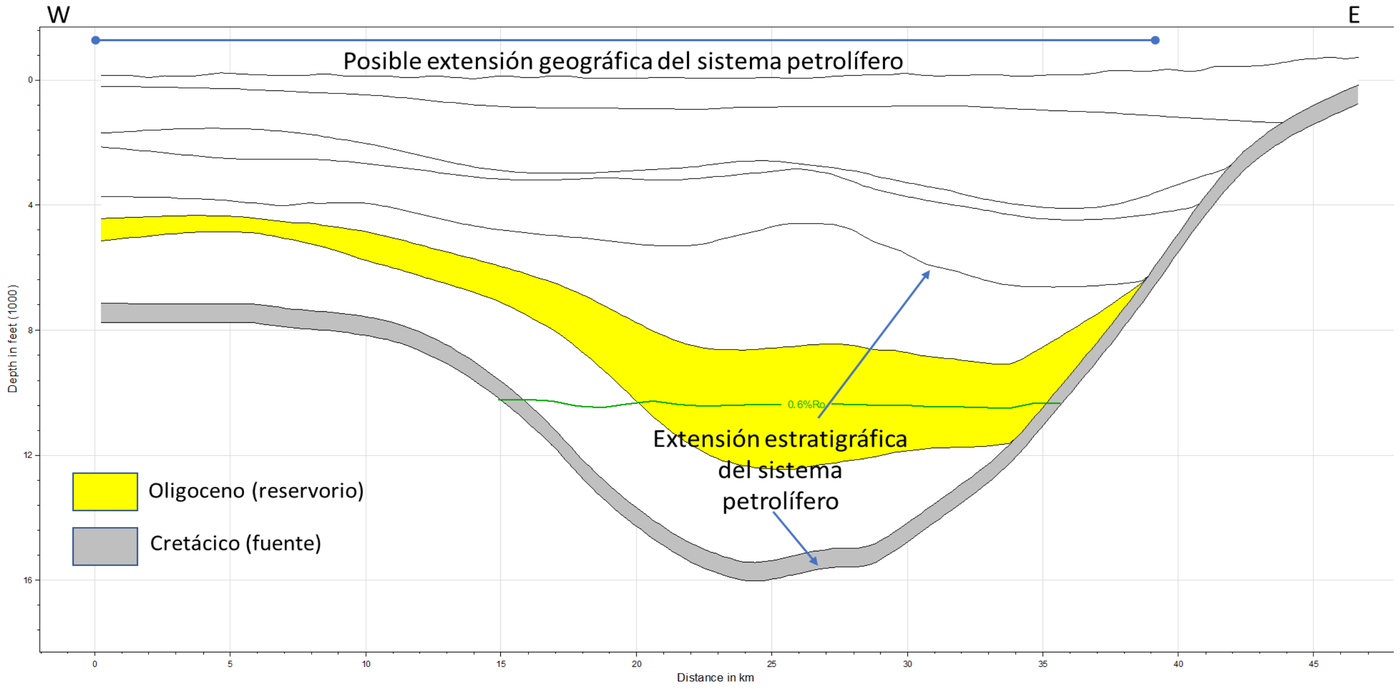
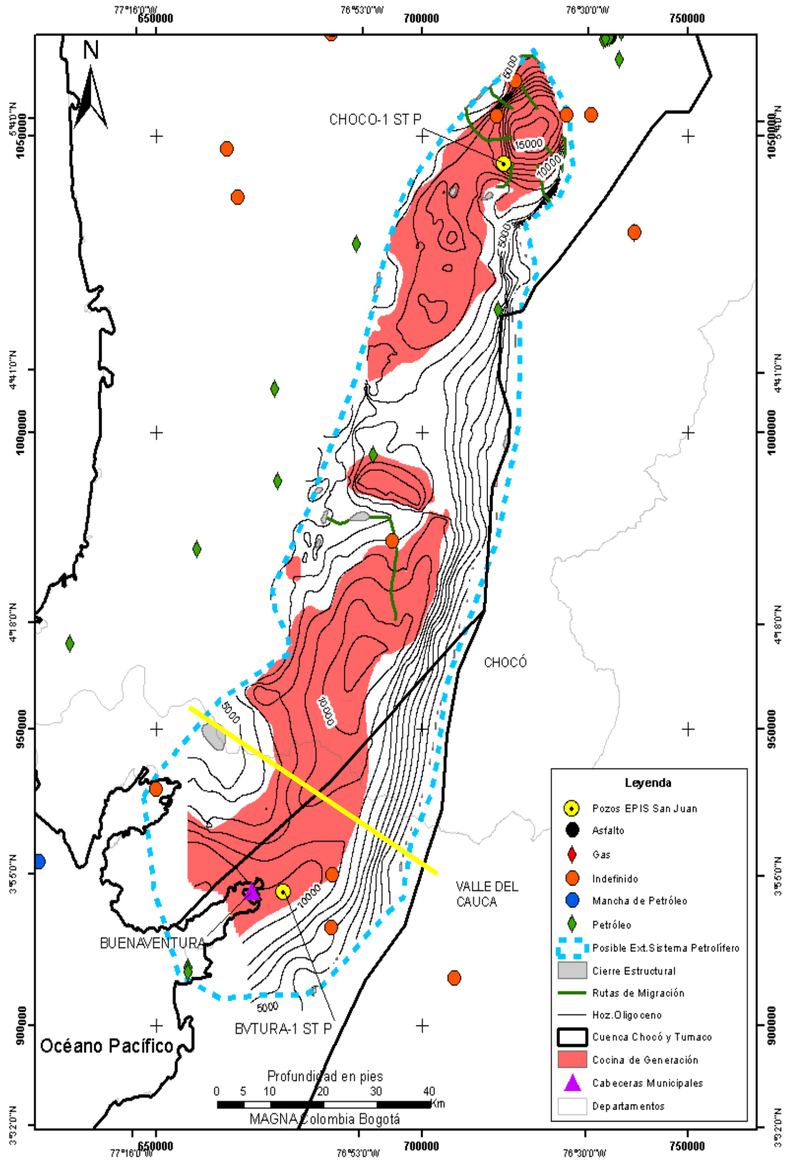
PETROLEUM SYSTEMS
TUMACO BASIN
Cretaceous – Oligocene (?)

Stratigraphic extent



Geographical extent



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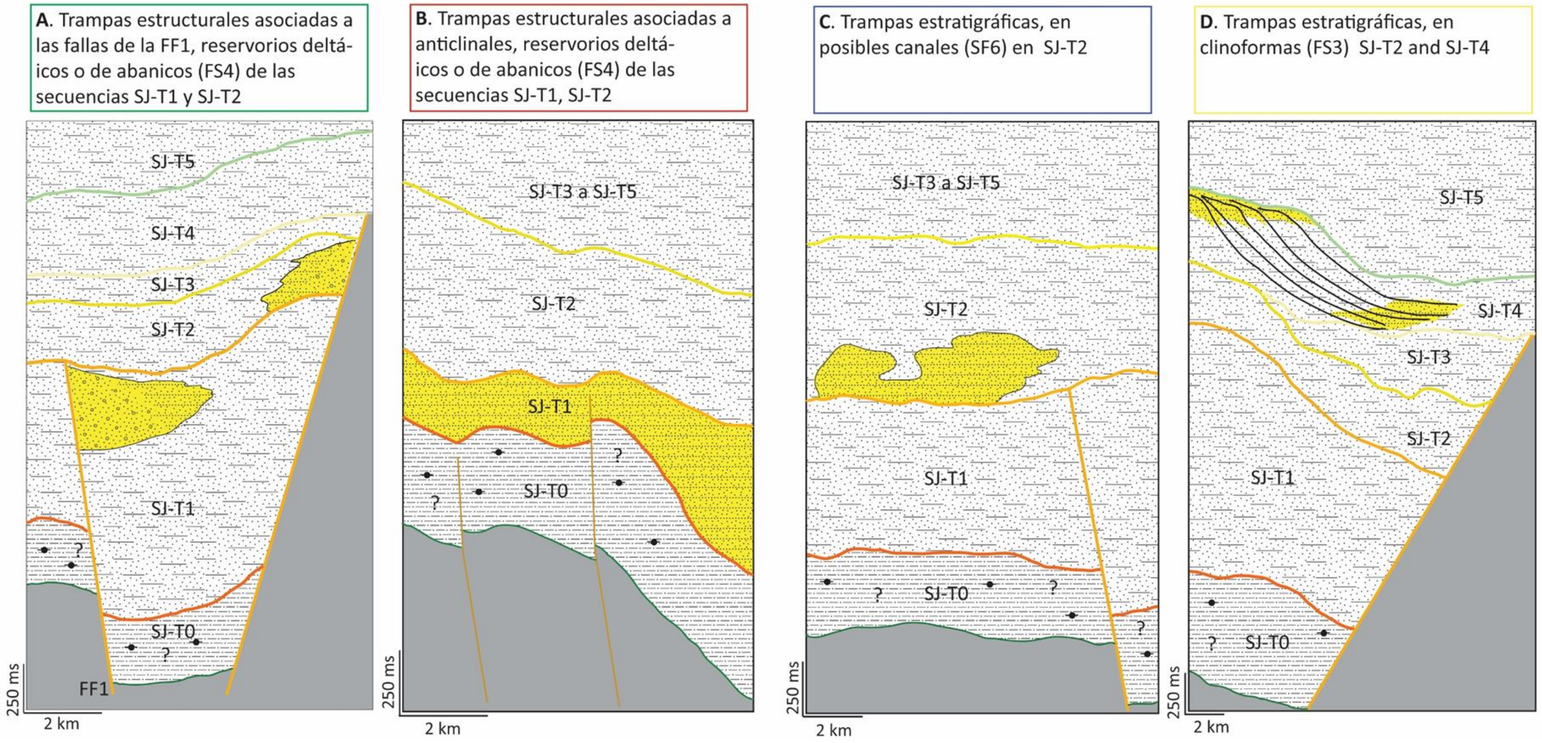
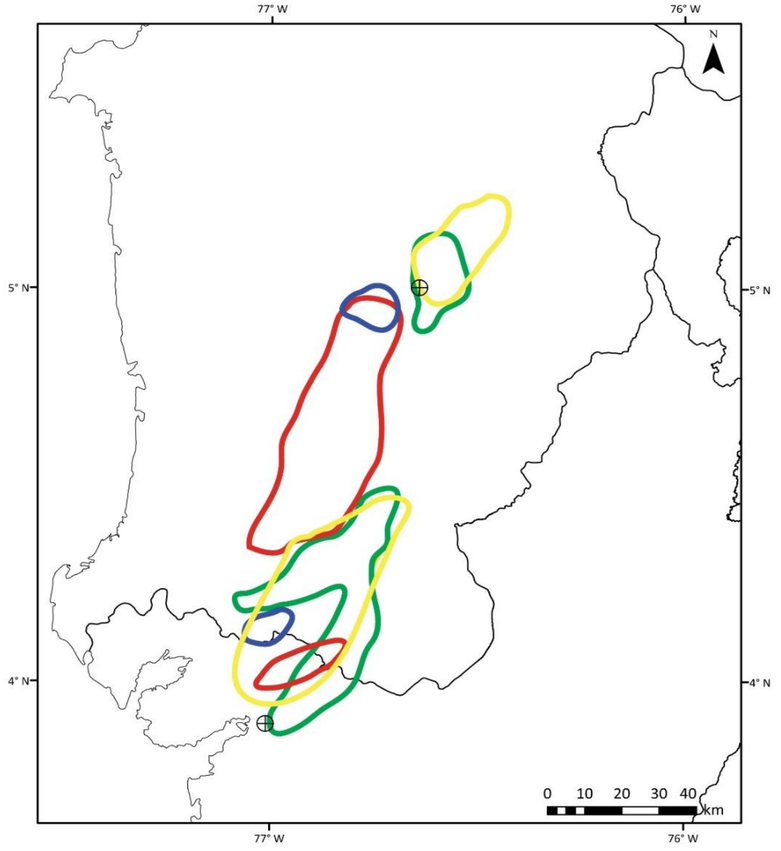
PROSPECTIVITY
SAN JUAN BASIN

Play concepts



Areal extent



A. Trampas estructurales asociadas a las fallas de la FF1 o FF3, reservorios deltáicos o de abanicos (FS4) de las secuencias SJ-T1 y SJ-T2

B. Trampas estructurales asociadas a anticlinales, reservorios deltáicos o de abanicos (FS4) de las secuencias SJ-T1, SJ-T2

C. Trampas estratigráficas, en posibles canales (SF6) en SJ-T2

D. Trampas estratigráficas, en clinoformas (FS3) SJ-T2 and SJ-T4

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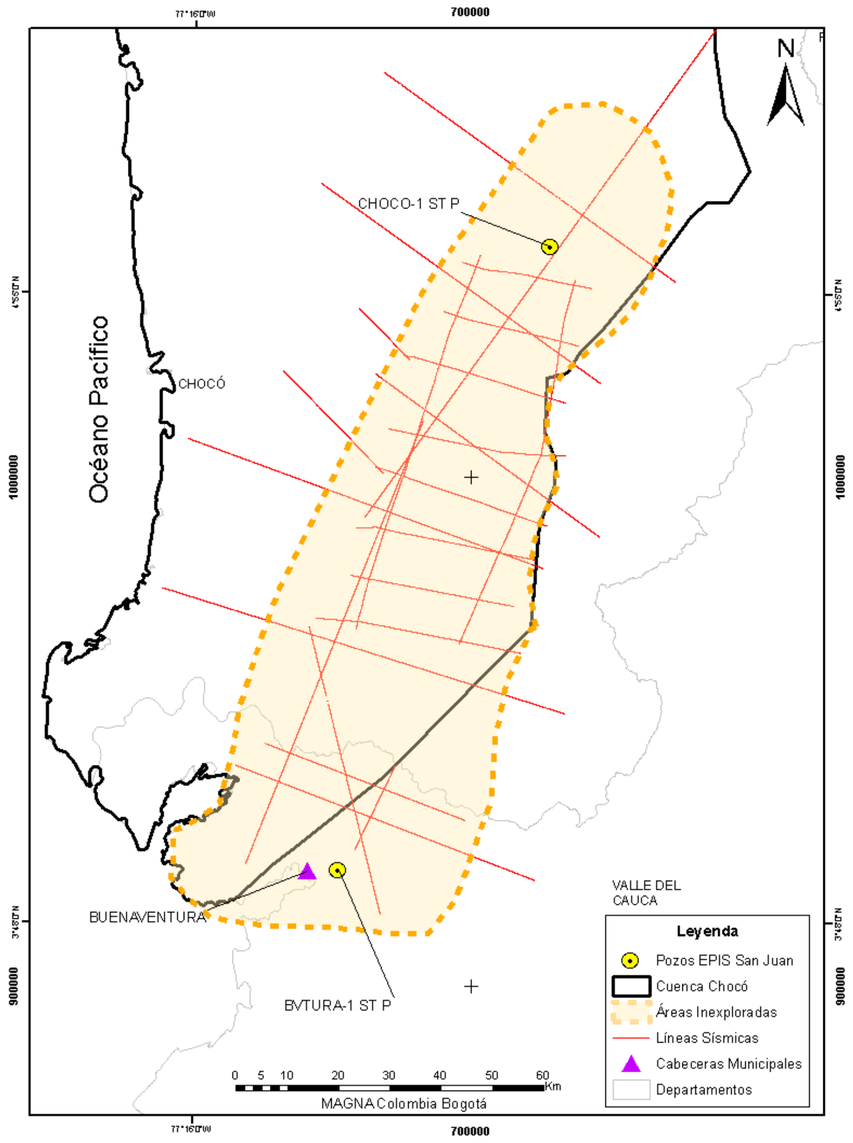
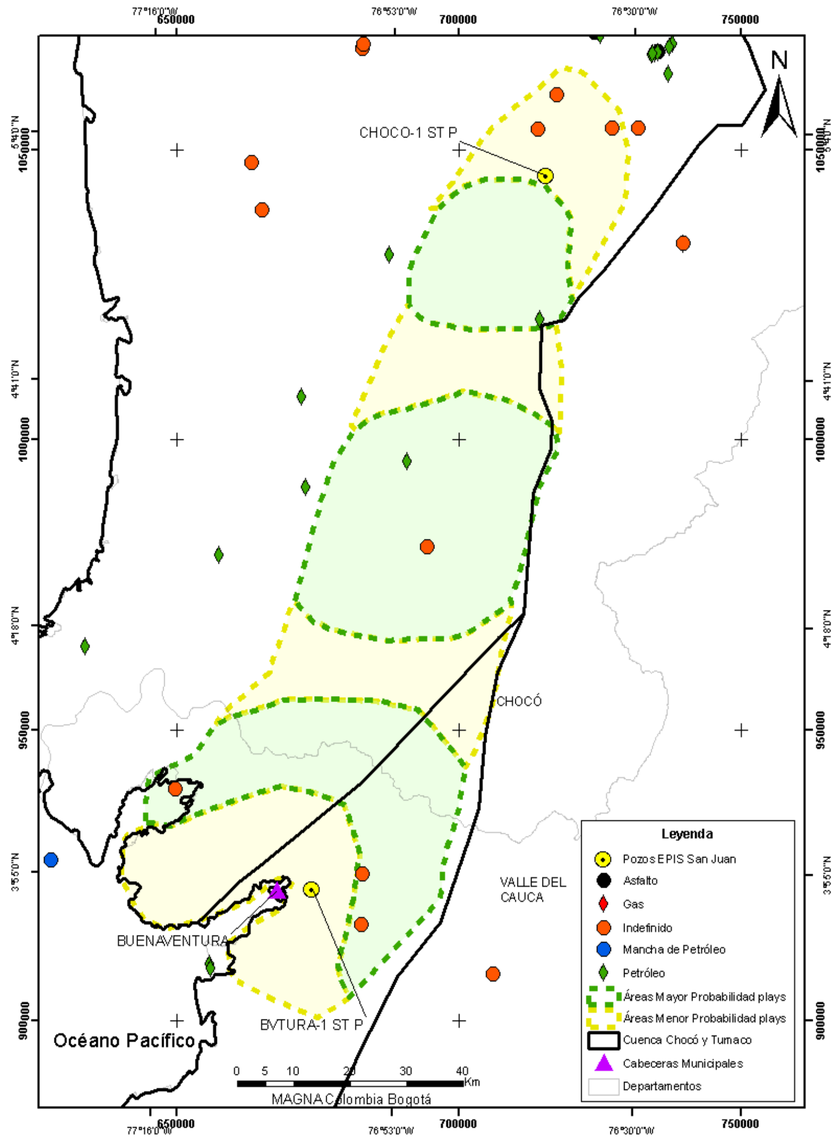
PROSPECTIVITY SAN JUAN BASIN

Underexplored areas



Exploratory corridors



YET TO FIND
SAN JUAN BASIN – PROSPECTIVE RESOURCES

San Juan

Pepper & Corvi (1995) - 3D	MBO	TCF
P_{10}	**6354.6**	**0.2**
P_{50}	**3916.8**	**0.1**
P_{90}	**2244.6**	**0.1**

Pepper & Corvi (1995) - 1D	MBO	TCF
Promedio	**2355.0**	**2.4**

Schmoker (1994) - Hunt (1995)	MBO	TCF
P_{10}	**2863.4**	**11.1**
P_{50}	**1593.0**	**5.3**
P_{90}	**367.7**	**1.0**

7. CONCLUSIONS

- ✓**Hydrocarbon manifestations in wells (shows) and at surface (seeps), are clear evidence of the existence of active petroleum systems in the Tumaco and San Juan basins.**
- ✓**The integration of data from organic geochemistry, thermal maturity, seismic interpretation, stratigraphy and basin modeling make it possible to postulate the existence of some speculative petroleum systems in the Tumaco Basin, involving potential late Cretaceous and Eocene source rocks, and potential reservoir rocks of Eocene, Middle Miocene and Late Miocene age.**
- ✓**In the case of the San Juan Basin, this integration allows to postulate the possible existence of speculative petroleum systems involving potential source rocks of Late Cretaceous and Eocene – Oligocene age, and rocks with reservoir potential of Eocene and Oligocene age.**

CONCLUSIONS

- ✓ **Is important to notice that due to the little information available in the study areas, the possibility of additional petroleum systems cannot be ruled out.**

- ✓ **Multiple play concepts have been identified for the Tumaco and San Juan basins that have not been tested, but there is need to acquire additional information to better delineate its extent and reduce uncertainties associated with them.**

- ✓ **The possible existence of multiple petroleum systems and the variety of play concepts identified and untested in the basins is encouraging for its prospectivity and discovery of economic accumulations.**

Thanks

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