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Organic Geochemistry Atlas of Colombia
Second Edition

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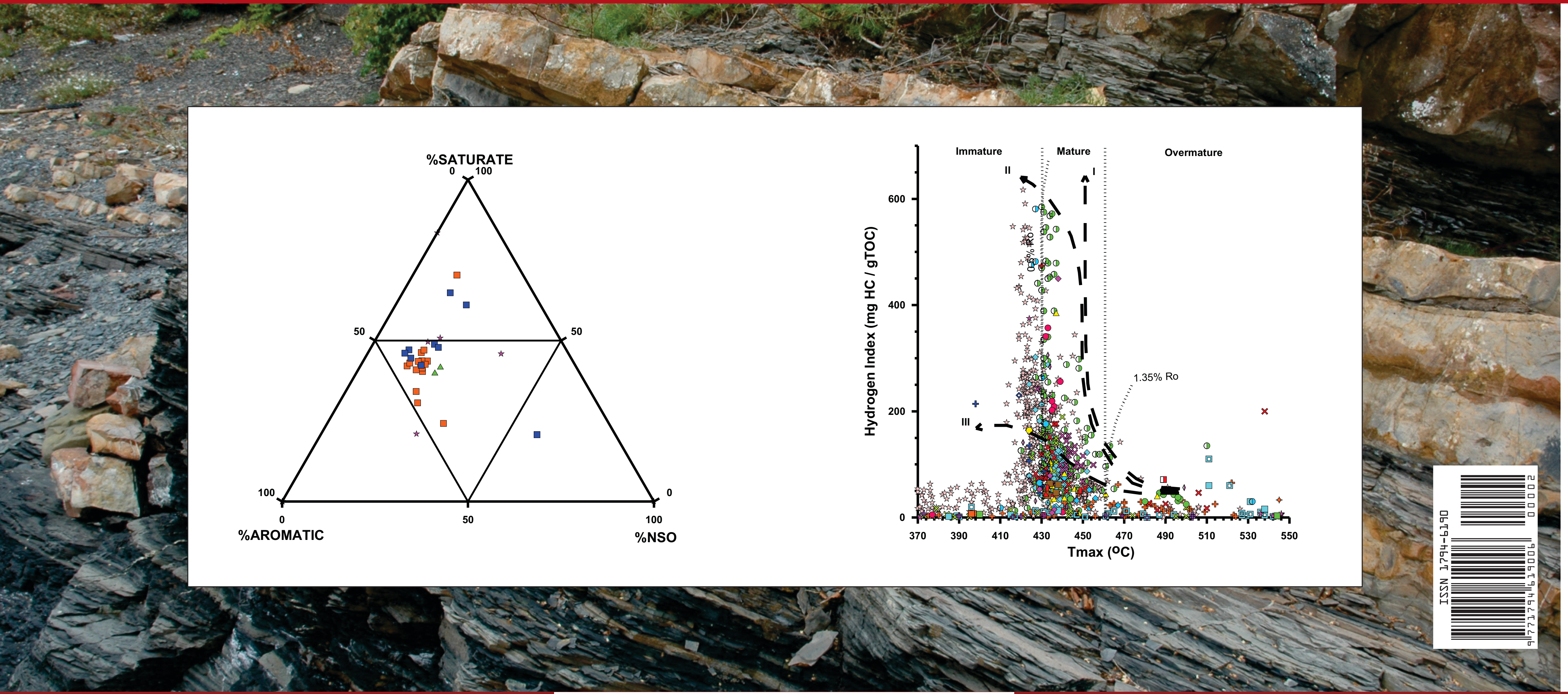

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Letter of Editor

“Science is the knowledge of consequences and the dependence of one fact on another”
Thomas Hobbes.

In a short time we are here again to offer you a new version of the Organic Geochemistry Atlas of Colombia. This effort is supported by the ANH, and extends the geochemical knowledge disposed in the previous version to new basins, and updated information up to 2009.

We hope that this document may be helpful to developers of projects of oil exploration and production, in a moment, when the exploration of new basins increases, and the oil associated activities are extended to new business.

This Atlas will serve as a guide for the oil industry as well as research centers and academic institutions, who may consult on their pages the state of knowledge in this field in Colombia, and the need to continue carrying out projects of this nature.

Can these pages help to answer questions like: Has the trap received economic quantities of petroleum?. What types of hydrocarbons are likely to be present (oil and/or gas and in what relative proportion)?. What are the oil or gas properties (e.g., viscosity, API gravity, sulfur content, etc.)? Is reservoir compartmentalization an issue?

We let the answers to our readers, from whom we hope to hear their findings and if possible their contribution.

Luis Montes
ESRJ Chief Editor

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Introduction

This new and updated edition Organic Geochemistry Atlas of Colombia provides the explorationist with an overview of the existing information on source rocks and crude oils in Colombia. The data compiled in this work is updated to 2009, and is found in the Organic Geochemistry Database of the Agencia Nacional de Hidrocarburos (ANH).

This updated version of the database includes 10329 new samples and 190836 associated geochemical data from pyrolysis, gas chromatography, liquid chromatography and surface geochemistry reports, from works developed by the ANH and exploration companies since 2003 to 2009. The references of the data sources included in this database can be found at the end of this volume.

This document is presented in a simple and graphical way to provide a quick look of the state of the art of the colombian basins, useful for newcomers or experts alike.

The Atlas is alphabetically organized, following the nomenclature and boundaries proposed by the ANH for the Colombian sedimentary basins (*Barrero et al*. 2007).

Includes geochemical information, from 18 basins, corresponding to source rock analyses, organic matter content (%TOC), Rock-Eval pyrolysis, organic petrography, crude oil and extract analyses, liquid chromatography, gas chromatography, biomarkers and isotopes.

All the graphs and conclusions are drawn from the information existing in the organic geochemistry database ,and were used for source rocks quality assesments and to generate crude oil and gas characterization graphs of depositional, maturity and quality parameters, along with quality and maturity maps of some of the main source rocks in Colombia.

Two new topics are present in this version of the Atlas, one about hydrocarbons origin from surface geochemistry data and the other about petroleum systems from crude-rock correlations.

These topics are treated in those basins in which surface geochemistry data, and where crude oil and rock extracts information, from reservoir and source rock units properly identified, exists.

Based on this information some insights on the source rocks, the origin of the hydrocarbons and petroleum systems found in the Colombian basins are presented.

The Organic Geochemistry Atlas of Colombia is intended to assist E&P professionals interested in understanding the origin and evolution of source rocks and crude/gas accumulations present in any of the colombian basins, and additionally as a guide on the future work that might be needed to improve the knowledge and reduce the exploratory risk, especially in frontier areas of Colombia.

Therefore, this new version of the Organic Geochemistry Atlas of Colombia is expected to become a valuable tool for exploration and educational purposes as well.

Methodology

Based on the organic geochemistry database of the ANH, compiled in 2010, an updated version of the Organic Geochemistry Atlas of the Colombian basins has been made.

In order to provide an overview of the knowledge on crude oil and source rock characteristics in the colombian basins, this volume has been structured in chapters containing information on the following subjects, depending on the information available for each basin:

- **Generalities**: Including location, stratigraphy, structural sections and highlights on the organic geochemistry data available and used in the interpretations presented.

- **Wells and Seeps**: location map of wells and/or surface locations with geochemical information and oil and gas seeps in the basin.

- **Crude Oil Quality**: Crossplots of quality-related, bulk analysis parameters like Ni/V, sulfur content, API gravity. These parameters give insights on the preservation or degradation of the oils, their maturity (API gravity and sulfur content), depositional conditions (sulfur content and Ni/V) and/or lithology of the source rocks (sulfur content).

- **Depositional Environments**: Crossplots of environment and organic facies related biomarkers and ratios (Peters and Moldowan, 1993), like Oleanane Index, Homohopane Index, Pristane, Phytane, Pristane/nC17, Phytane/nC18, C27, C28 and C29 steranes. These parameters provides information on the type of organic matter terrestrial, marine or mixed (pristane/nC17 vs phytane/nC18, C27-C29 steranes, oleanane index), bottom oxicity (homohopane index, pristane/nC17vs phytane/nC18), depositional environments(homohopane index, oleanane index, pristane/phytane) and even age of the source rocks (oleanane index).

- **Chromatography**: Typical examples of whole oil chromatograms and fragmentograms (m/z 191and m/z 217) showing the degree of preservation and processes affecting the accumulations like mixing of different thermal maturity oils (refreshing) and biodegradation.

- **Source Rock Characterization**: In order to show the quality and maturity of the source rocks, crossplots based on Pyrolysis Rock-Eval and organic petrology data has been made. The parameters used to estimate quality are organic matter content (%TOC),Hydrogen Index, Oxygen Index, and generative potential (S2 peak).The maturity parameters used were Pyrolysis Tmax in degrees Celsius, and vitrinite reflectance (%Ro). In the following tables are summarized the general values used for interpretation of these data.

Organic matter generation potential:

Generation Potential	TOC (wt %)	Rock-Eval S2 Peak (mg HC/ g rock)
Poor	0 - 0.5	0 - 2.5
Fair	0.5 - 1	2.5 - 5
Good	1 - 2	5 - 10
Very Good	2 - 4	10 - 20
Excellent	> 4	> 20

Kerogen Type	Hydrogen Index (mg HC/ g TOC)
I	> 600
II	300 - 600
III	50 -200
IV	< 50

Methodology

Thermal Maturity	Rock-Eval Tmax (°C)	Vitrinite Reflectance Ro (%)
Immature	< 435°	0.2 - 0.6
Early Mature	435° - 445°	0.6 - 0.65
Generation Peak	445° - 450°	0.65 - 0.9
Late Mature	450° - 470°	0.9 - 1.35
Overmature	> 470°	> 1.35

- **Source Rock Quality and Maturity Maps**: These maps were generated based on organic matter content (%TOC), Hydrogen Index and Tmax information available.

- **Gas Characterization**: Crossplots of gas molecular composition and stable carbon isotopes of methane, ethane and propane were made in order to establish the origin and generation conditions of the gases found in the basins.

- **Surface Geochemistry**: Bernard and compositional plots of sorbed gases in soil samples were made to help establishing its origin (thermogenic or biogenic) (Whiticar, 1990).

- **Petroleum Systems (Crude - Rock Correlations)**: Based on the crossplots used for depositional environments determination, a series of correlations of crude oil from reservoirs and extracts from potential source rocks were made in order to better establish petroleum systems, following the nomenclature proposed by Magoon and Dow (1994), in which the name of a petroleum system contains three parts:

1. The source rock in the pod of active source rock.
2. The name of the reservoir rock that contains the largest volume of petroleum.
3. The symbol expressing the level of certainty.

The table below shows how the level of certainty is determined for a petroleum system (Magoon and Dow, 1994).

Level of Certainty	Criteria	Symbol
Known	A positive oil-source rock or gas -source rock geochemical correlation	(!)
Hypothetical	In the absence of a positive petroleum-source rock correlation, geochemical evidence	(.)
Speculative	Geological or geophysical evidence	(?)

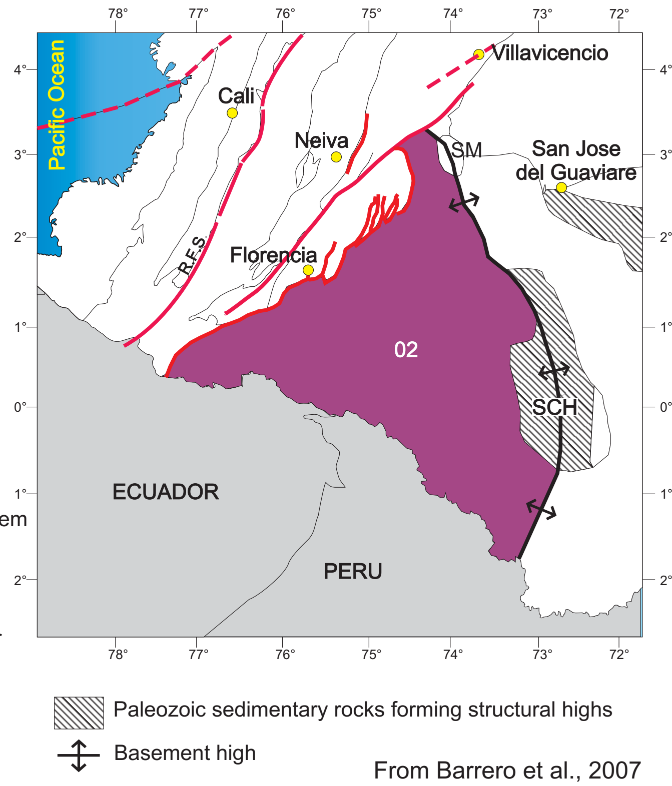
Based on these crossplots and maps some general conclusions on the crude oils , source rocks, gases and petroleum systems are presented for each basin.

CAGUÁN-PUTUMAYO BASIN

Generalities
Wells and Seeps
Crude Oil Quality
Depositional Environments
Chromatography
Source Rock Characterization
Source Rock Quality and Maturity Maps
Petroleum Systems (Crude-Rock Correlations)

Generalities

CAGUAN - PUTUMAYO BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

Northwest: Eastern Cordillera Foothills fault system

Northeast: Sierra de la Macarena (SM)

East: Structural high, including the Serranía de Chiribiquete (SCH)

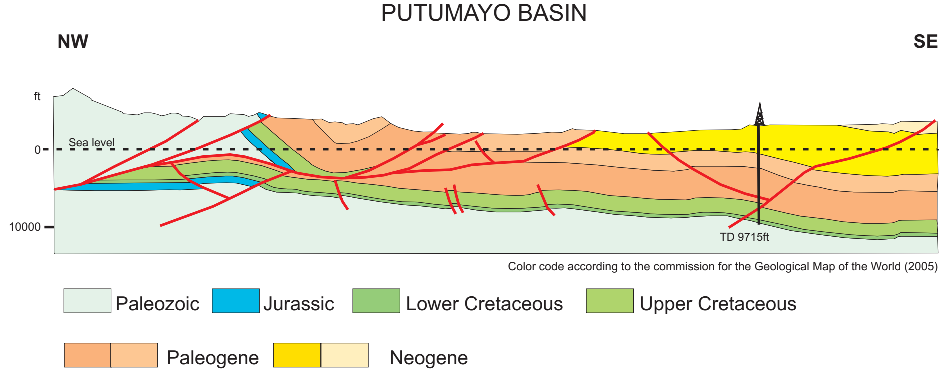
South: Ecuadorian-Peruvian International border

From Barrero et al., 2007

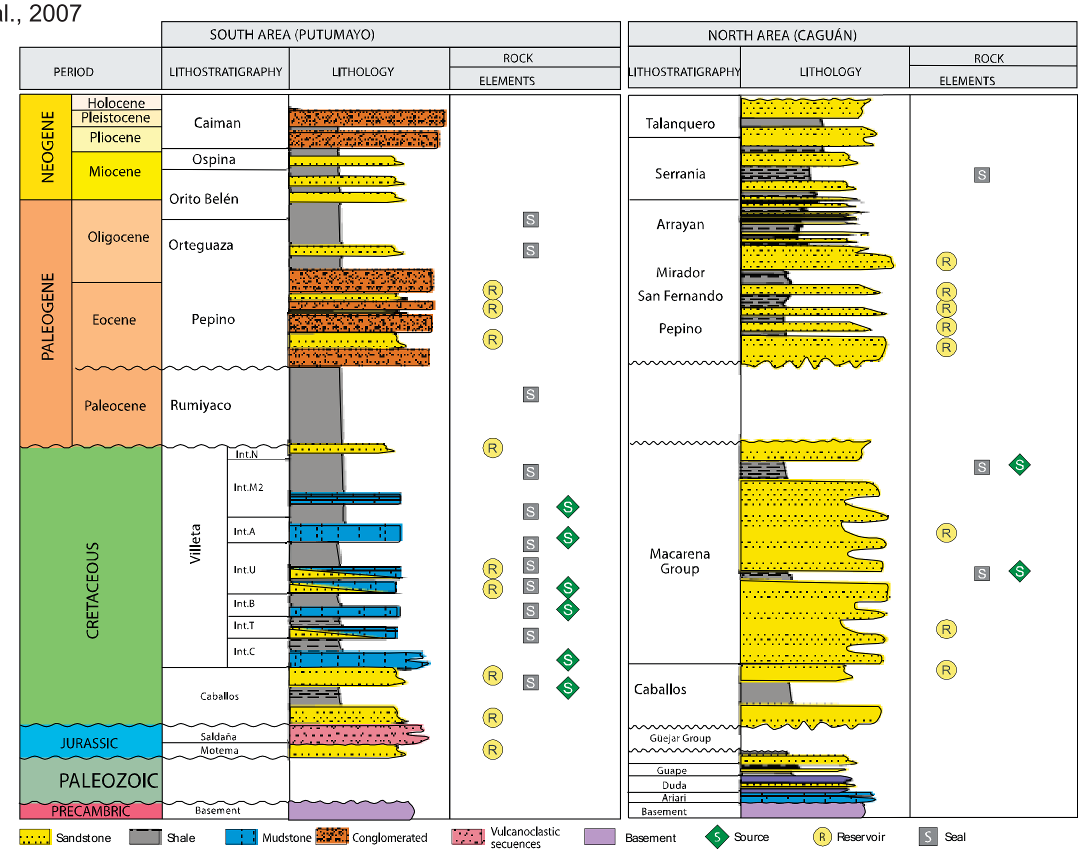
The source rock geochemical information interpreted for the Caguán-Putumayo Basin includes %TOC and Rock-Eval Pyrolysis data from 2912 samples taken in 64 wells; additionally 335 organic petrography samples from 56 wells were interpreted.

Crude oil and extracts information from 124 bulk analysis samples, 403 liquid chromatography samples, 330 gas chromatography samples,582 biomarker samples and 90 isotopes samples were also interpreted.

SCHEMATIC CROSS SECTION
PUTUMAYO BASIN

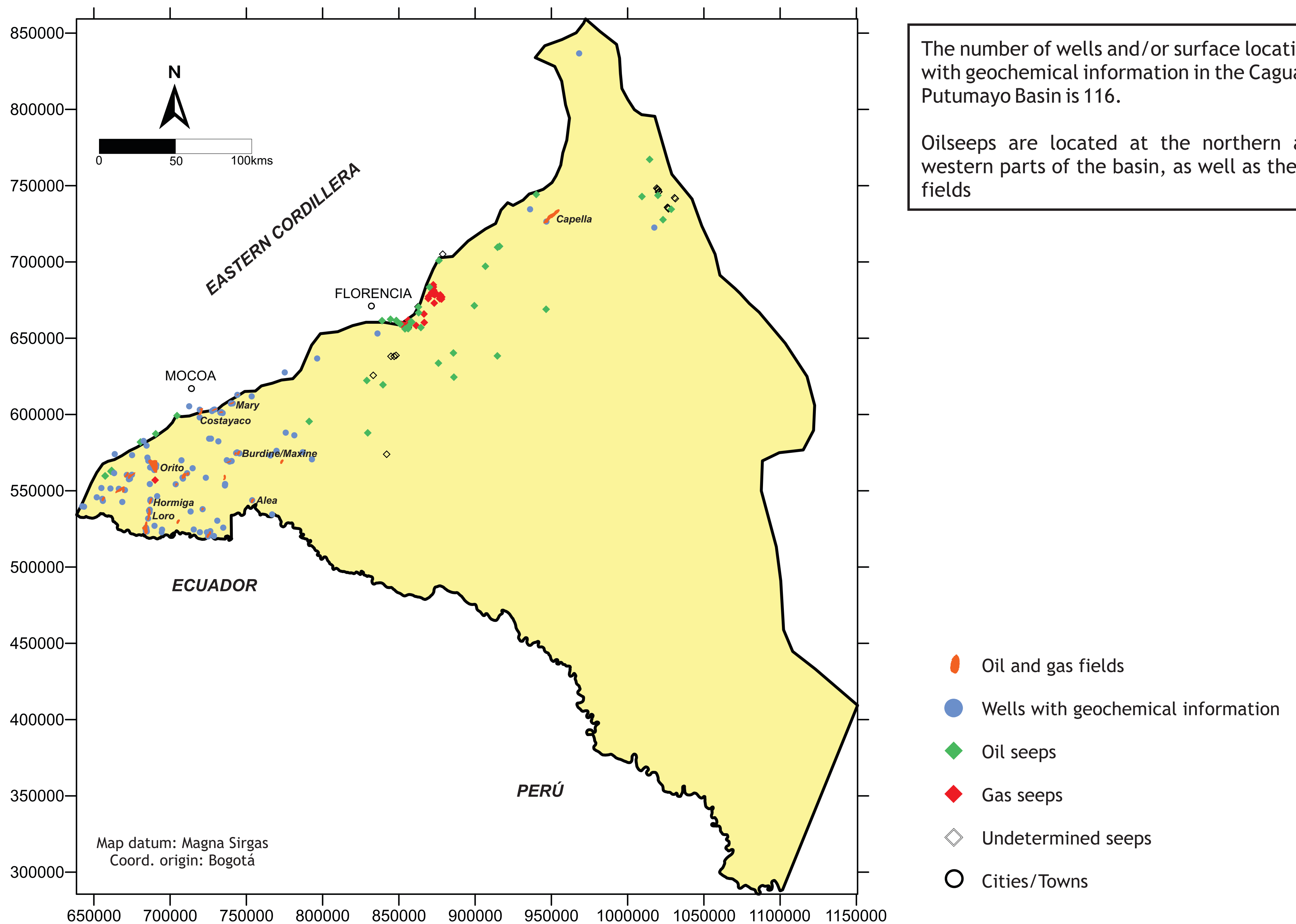


From Barrero et al., 2007



From Mojica et al., 2010

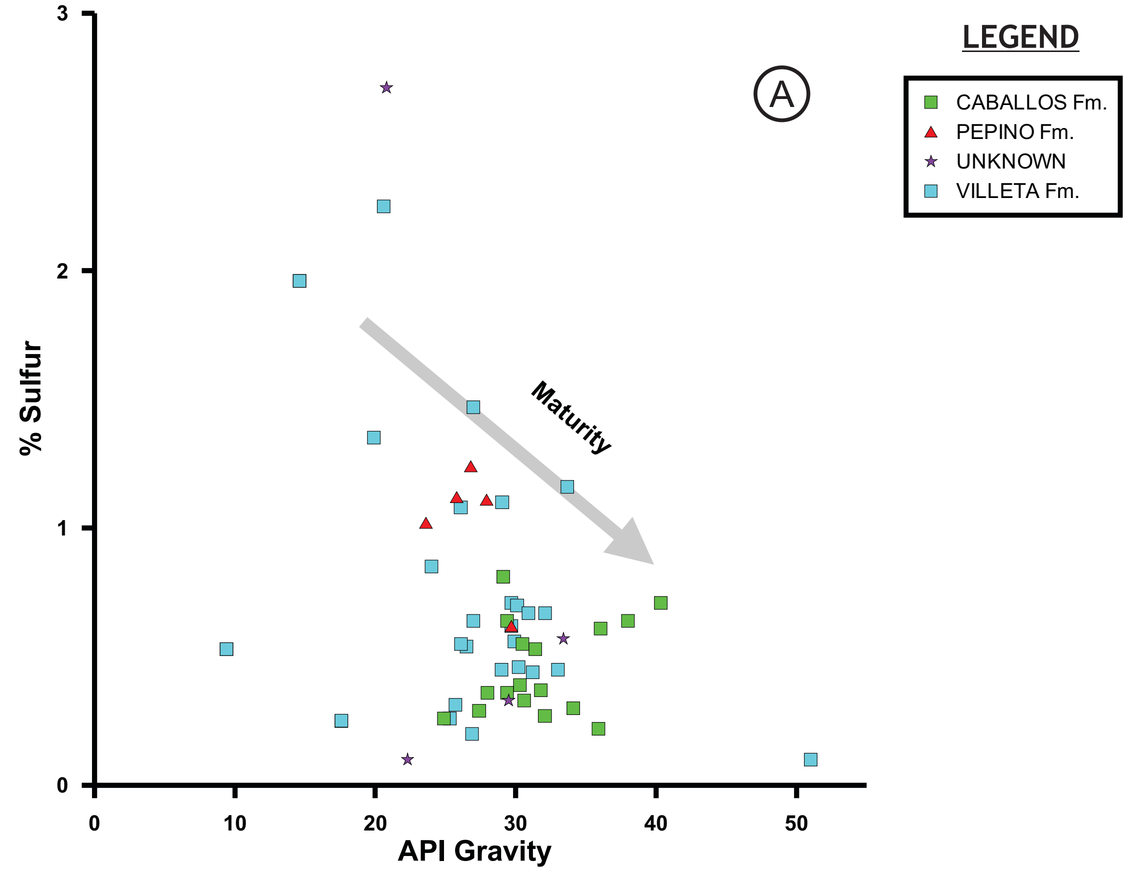
Wells and Seeps

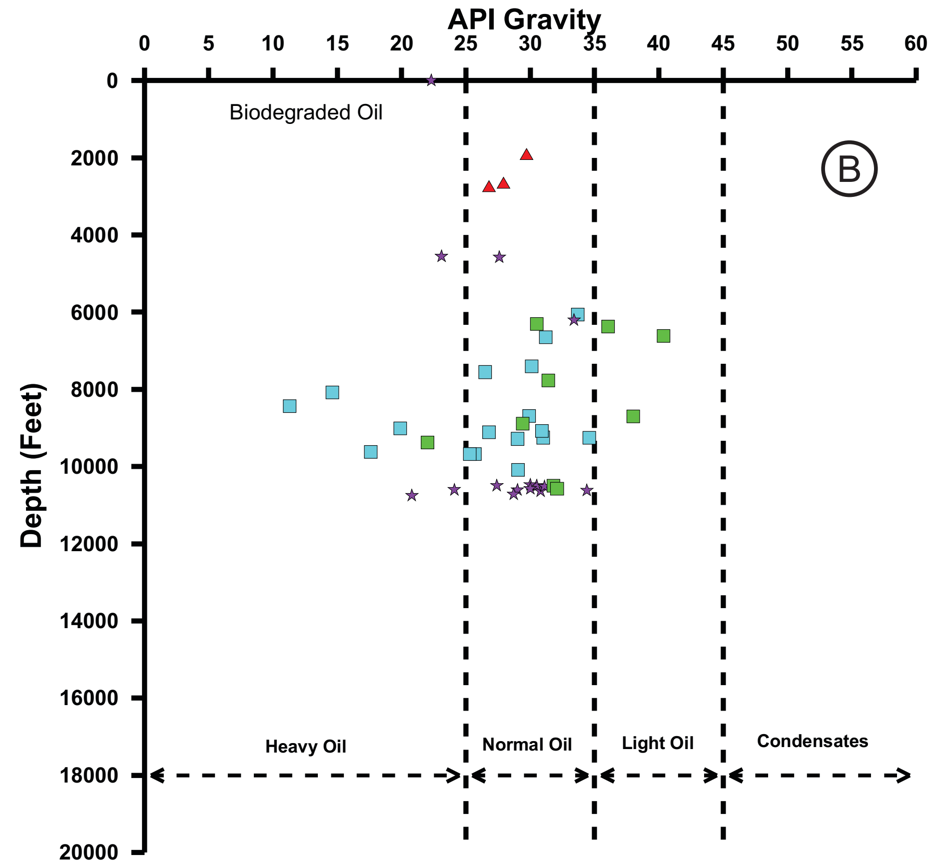


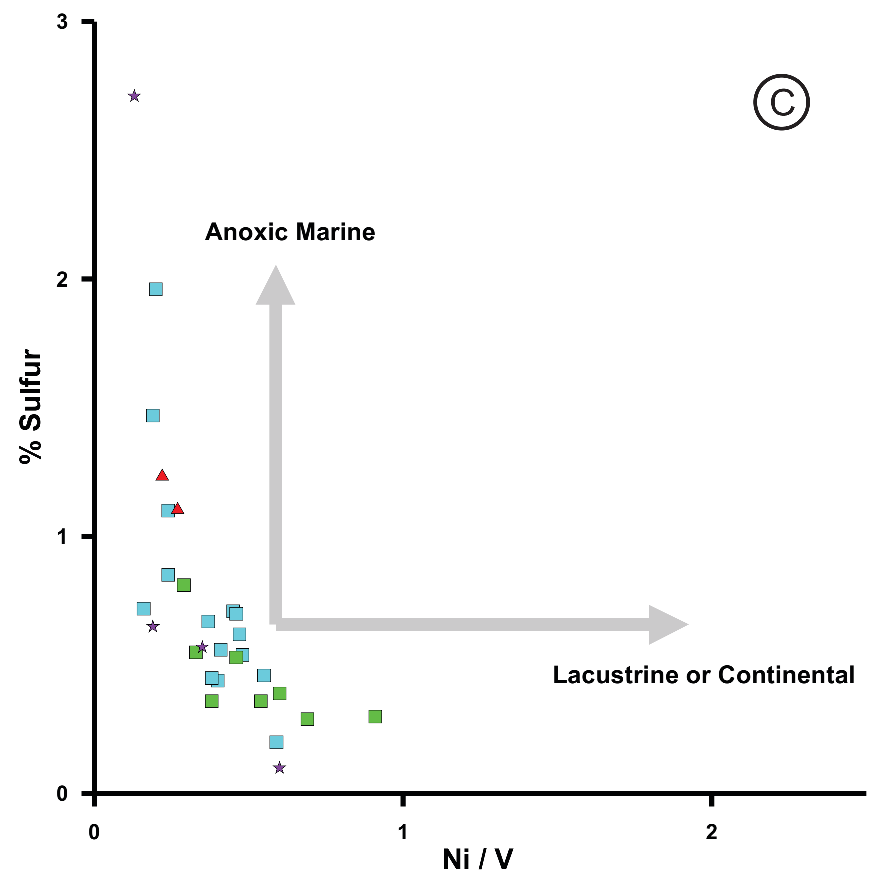
The number of wells and/or surface locations with geochemical information in the Caguán - Putumayo Basin is 116.

Oilseeps are located at the northern and western parts of the basin, as well as the oil fields

Crude Oil Quality





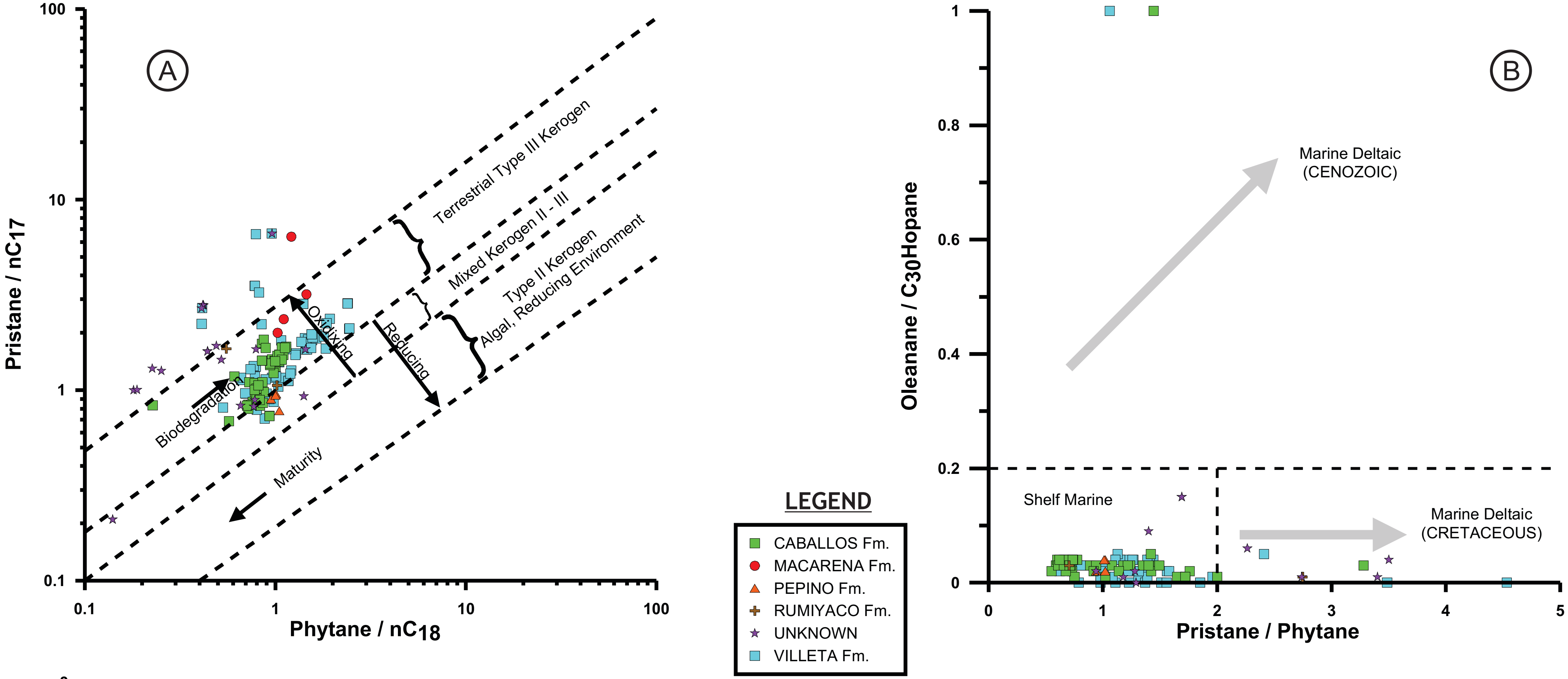


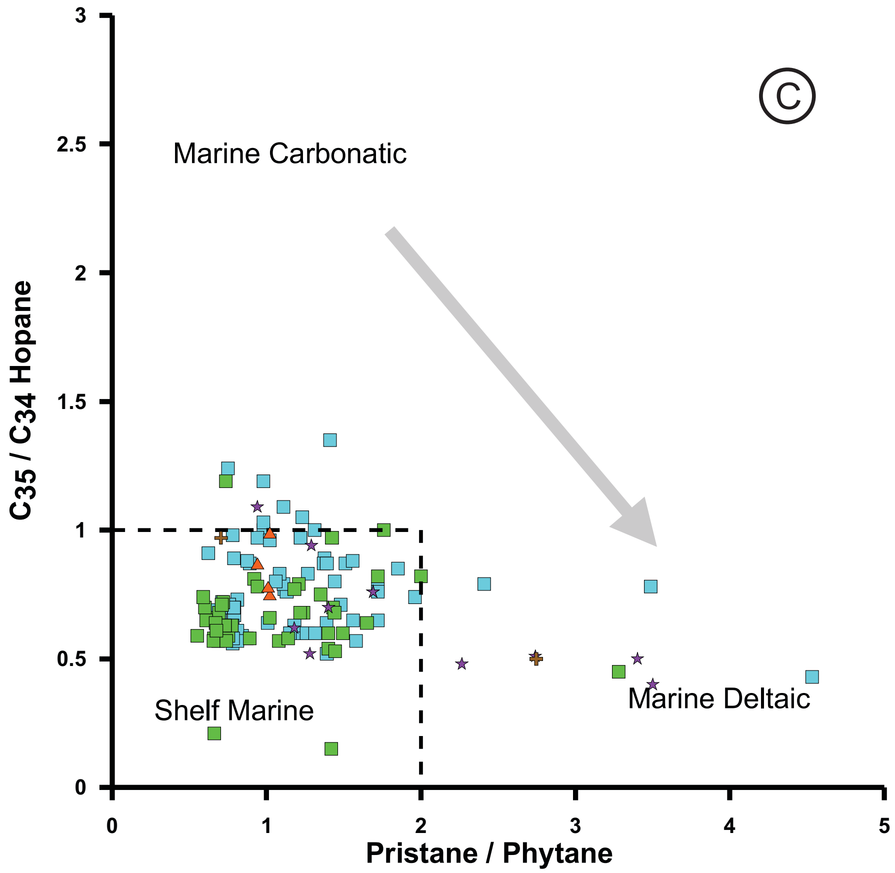
- Normal and light oils with API gravities ranging from 10° to 40° and sulfur content between 0 and 3% are present in the basin. There is no straight relationship between sulfur and API gravity, but oils above 30° API have sulfur values below 1%, and oils below 30° show higher dispersion in sulfur content with values up to 3%. This suggests that in the basin there are oils with different thermal maturities,the more mature have higher API gravity and lower sulfur content; but there are also crudes that having similar API gravities have different sulfur contents, which might indicate biodegradation, increasing sulfur content, and/or different source rocks, considering that oils sourced from shales usually have lower sulfur content than oils from carbonates (Figure A).

- There is no direct relationship between depth and crude oil quality, indicating that similar quality oils can be found at different stratigraphic levels, probably related to vertical migration in faulted reservoirs. But additionally there is the fact that different API gravity oils can be found at similar depths, reflecting different preservation (biodegradation) and/or thermal maturities (Figure B).

- The sulfur content of most crude oils is lower than 1%, and its Ni/V ratio below 0.5, suggesting that they are produced from rocks deposited in a marine suboxic environment with low terrigenous organic matter input (Figure C).

Depositional Environments



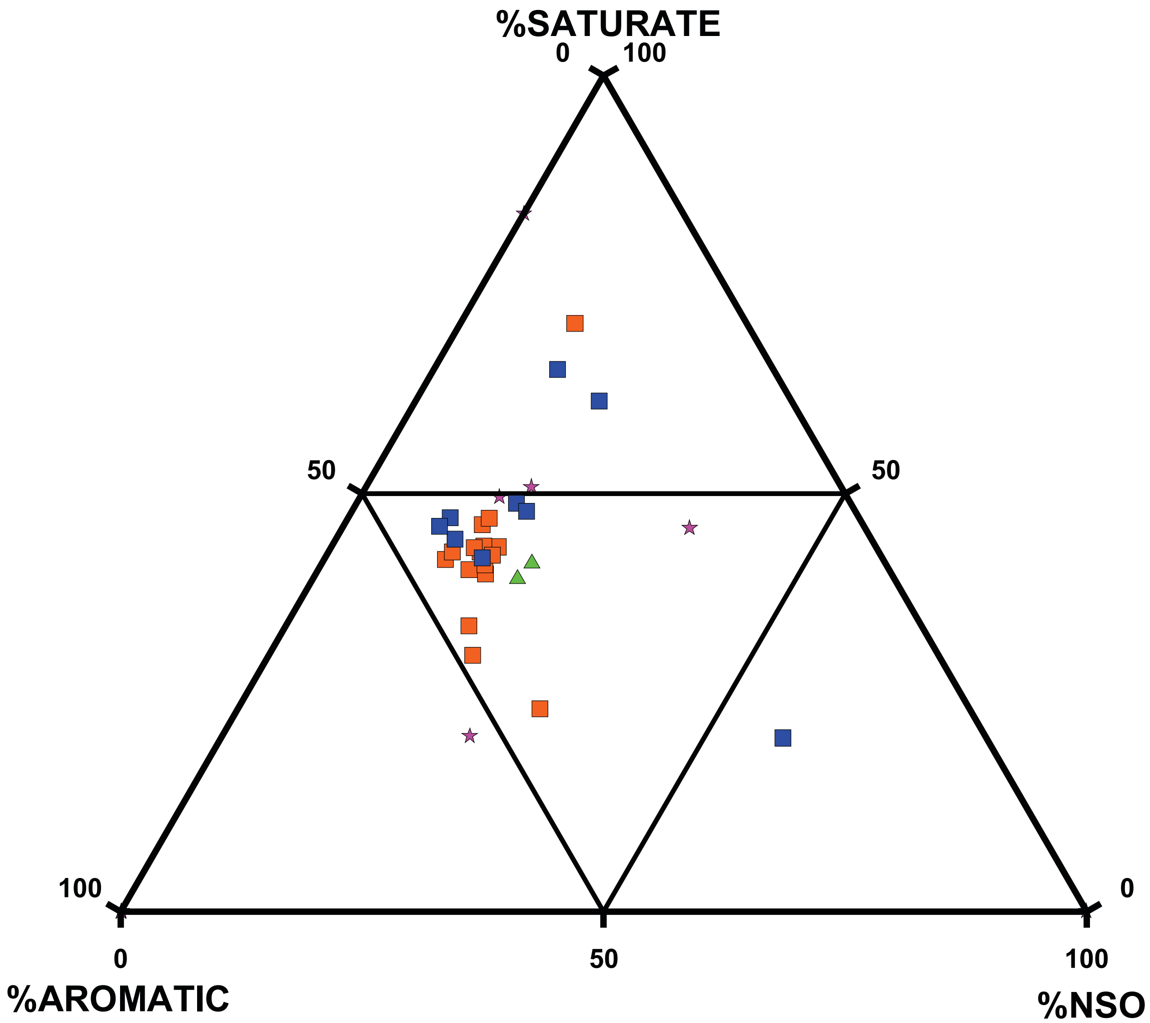


- The Phytane/nC18 vs Pristane/nC17 graph indicates that most of the oils have origin from terrestrial organic matter (Type III kerogen) deposited in an oxidizing environment and have suffered low biodegradation. There are also some samples in the mixed kerogen range suggesting a source with terrestrial and marine organic matter (Type II and III kerogens) deposited in more reducing conditions (Figure A).

- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that most of the oils have low oleanane index values (<0.2) and Pr/Ph values (<2) which indicates that these oils are generated from source rocks deposited in shelf marine environments. There are some samples with low oleanane index values but high Pr/Ph (>2) indicating that these oils were generated from source rocks deposited in marine deltaic environments. The oleanane index has been also used as an age indicator of the source rock, with high oleanane values for oils generated in Cenozoic rocks and low oleanane values in oils from older rocks (Figure B).

- The Pristane/Phytane vs C35/C34 Hopane (Homohopane index) graph shows that most oil samples have Pr/Ph values below 2 and C35/C34 Hopane below 1, indicating that these oils were generated from siliciclastic rocks deposited in a shelf marine environment. Additionally there are some samples with low homohopane index but higher Pr/Ph values (>2) indicative of siliciclastic rocks deposited in marine deltaic environments (Figure C).

Depositional Environments



- The liquid chromatography data (saturates, aromatics and NSO compunds) from oils in the basin are plotted in the ternary diagram above, and their distribution indicate that oils are well preserved having low biodegradation (low %NSO compounds).

- In summary, the crude oils in the basin correspond predominantly with generating facies deposited in siliciclastic environments ranging from marine to deltaic with an important terrestrial organic matter input. These rocks were deposited during the Cretaceous considering their low oleanane index values corresponding to the Villeta and Caballos formations.

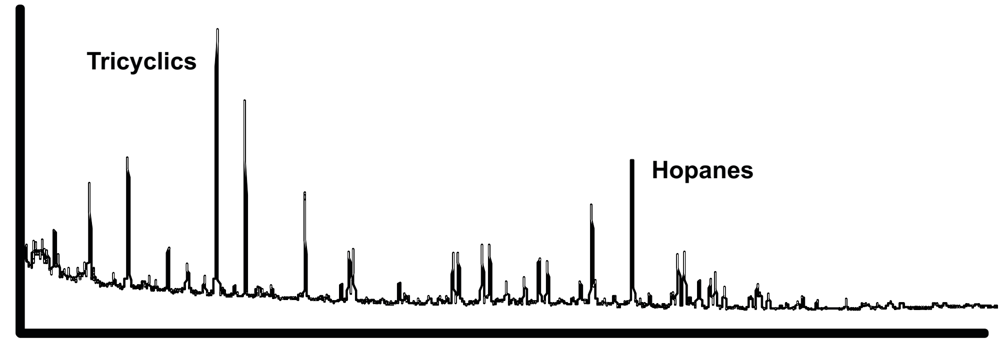
- These crude oils are of good quality with API gravities above 25° and sulfur content below 1% for most of them, and are well preserved (low biodegradation).

- Hydrocarbons have been found in reservoirs corresponding to the Caballos, Villeta and Macarena formations of Cretaceous age and the Cenozoic Pepino and Rumiyaco formations.

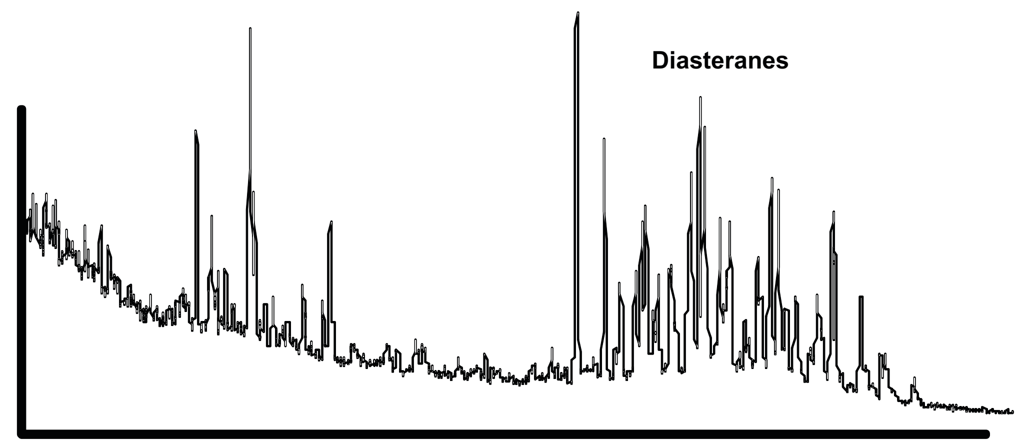
Chromatography

Crude oil of the Orito-16 well shows predominance of low molecular weight paraffins and Pristane/Phytane ratio close to 1.

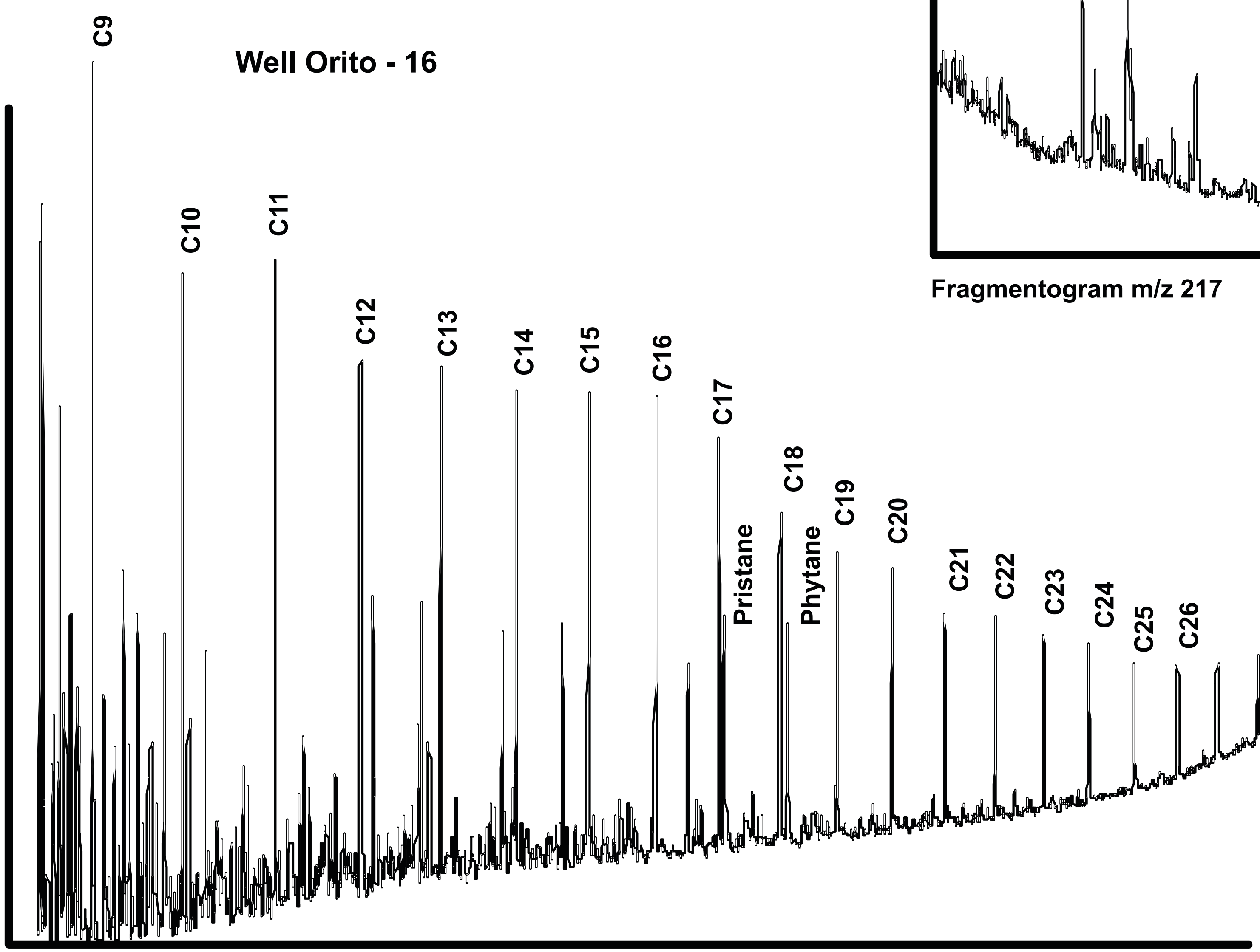
This crude shows predominance of tricyclics over hopanes indicating high thermal maturity. The diasteranes abundance suggests that the oil was generated from clay-rich rocks but also increased thermal maturity.



Fragmentogram m/z 191



Fragmentogram m/z 217

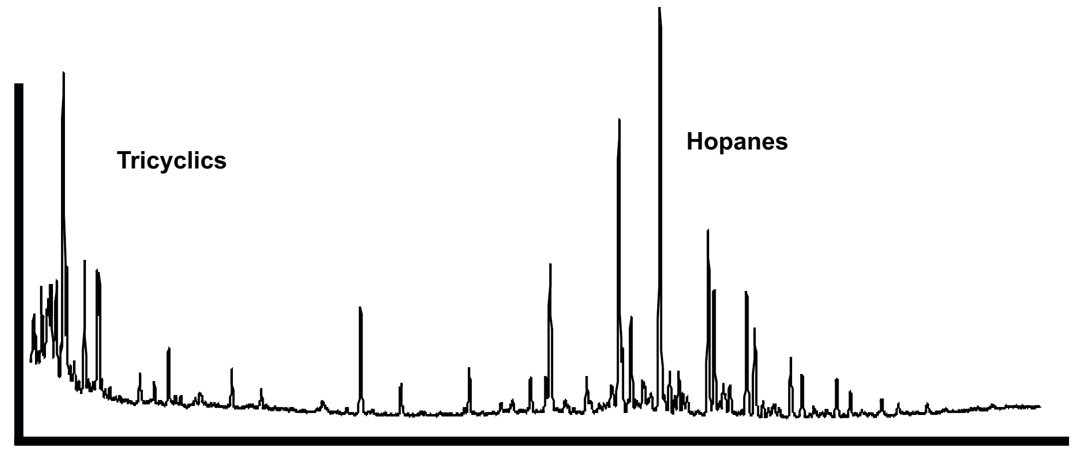


Chromatogram

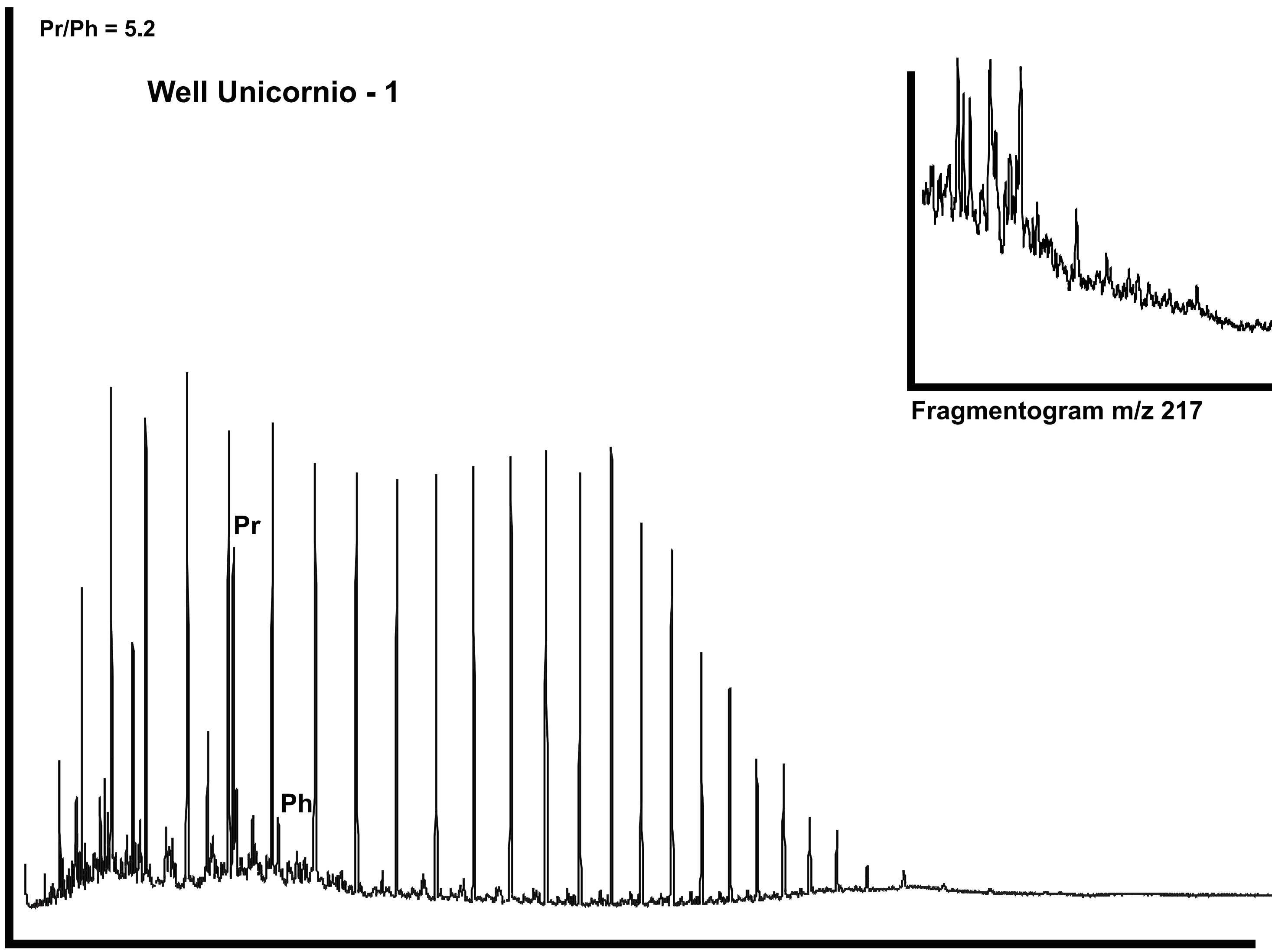
Chromatography

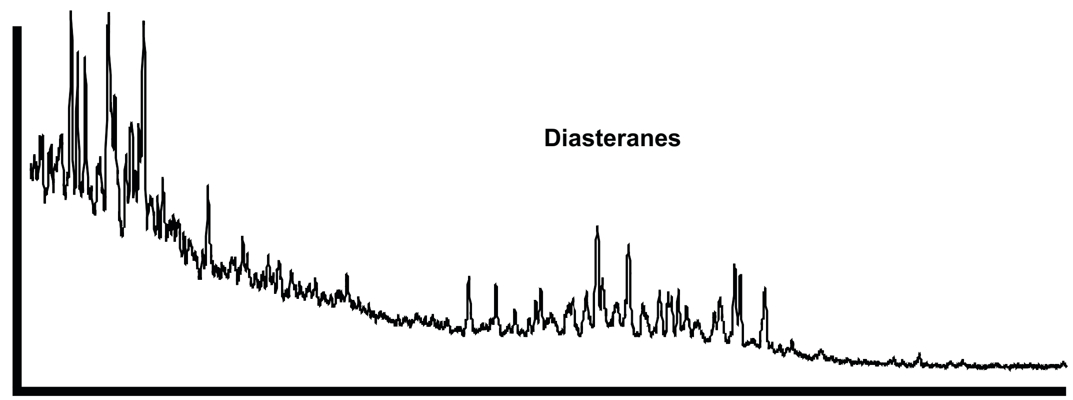
Crude oil of the Unicornio-1 well shows a bimodal chromatogram with high molecular weight paraffins abundance and very high Pristane/Phytane ratio (>5.0), indicating generation from organic facies deposited in deltaic environments.

The predominance of hopanes over tricyclics indicates low thermal maturity of the oil. The low diasteranes abundance suggests that the oil was generated from clay-poor rocks.



Fragmentogram m/z 191

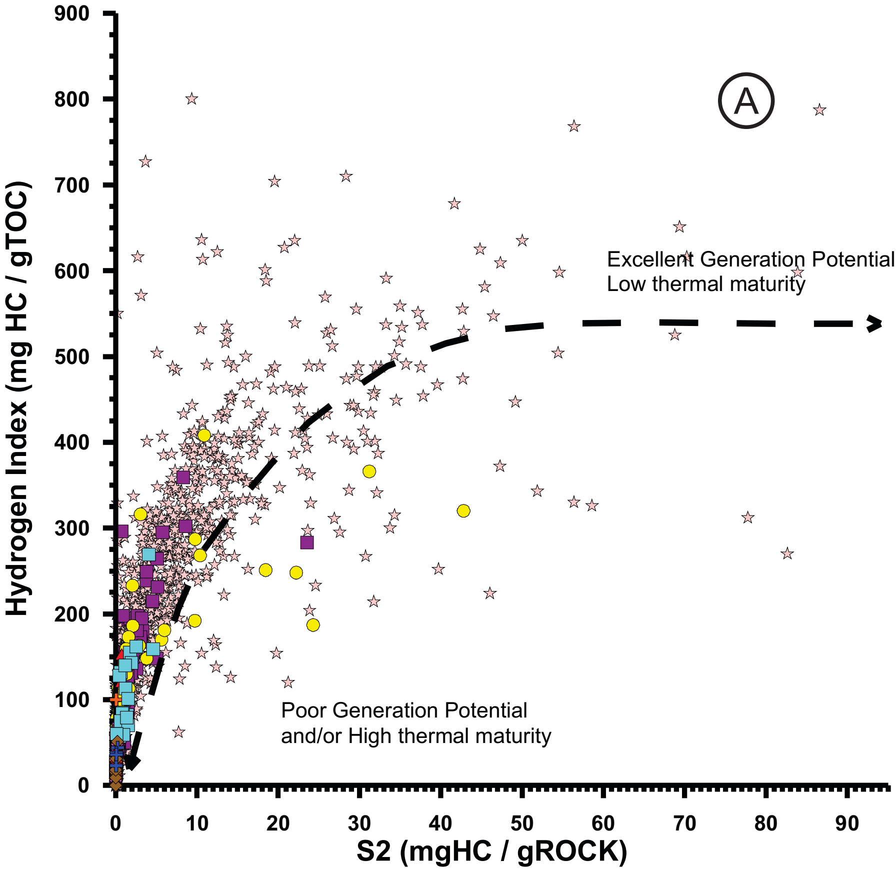


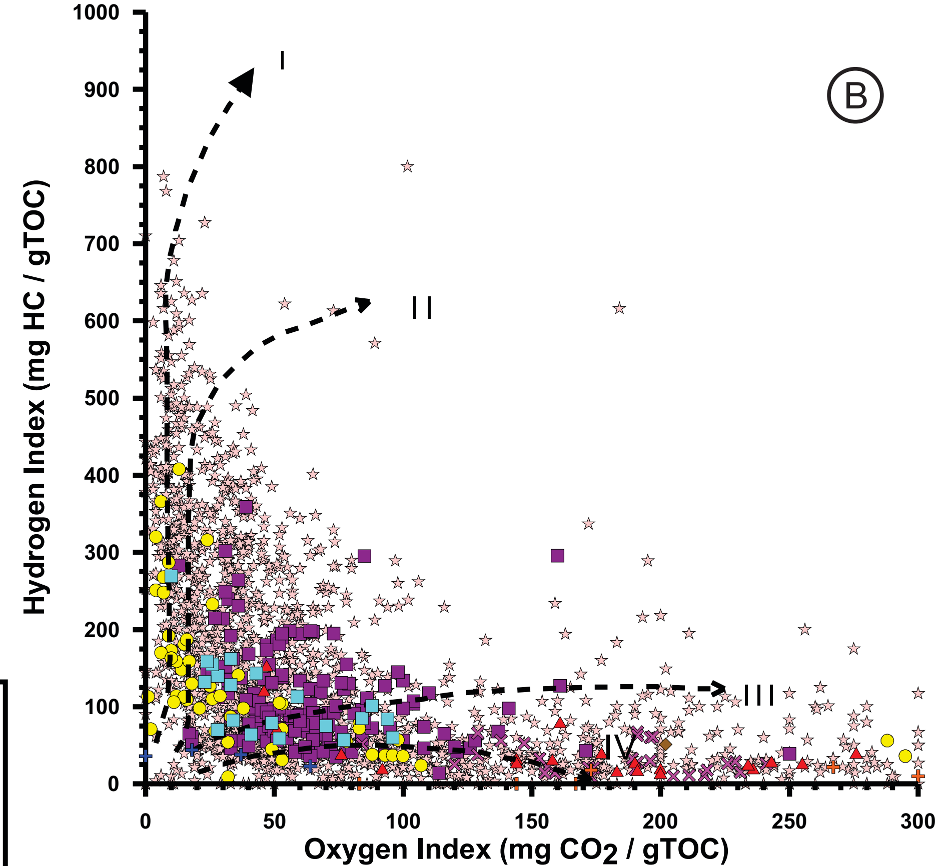


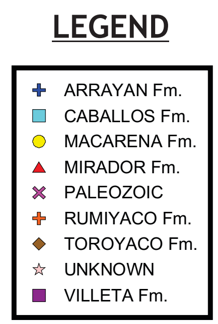
Fragmentogram m/z 217

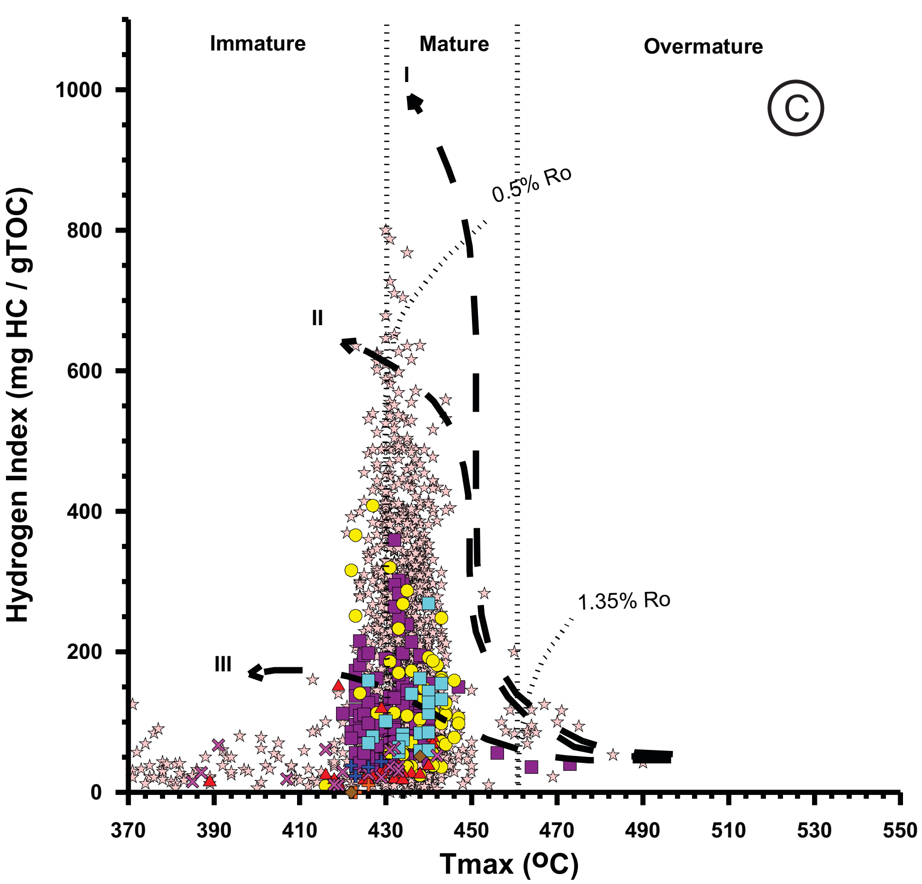
Chromatogram

Source Rock Characterization







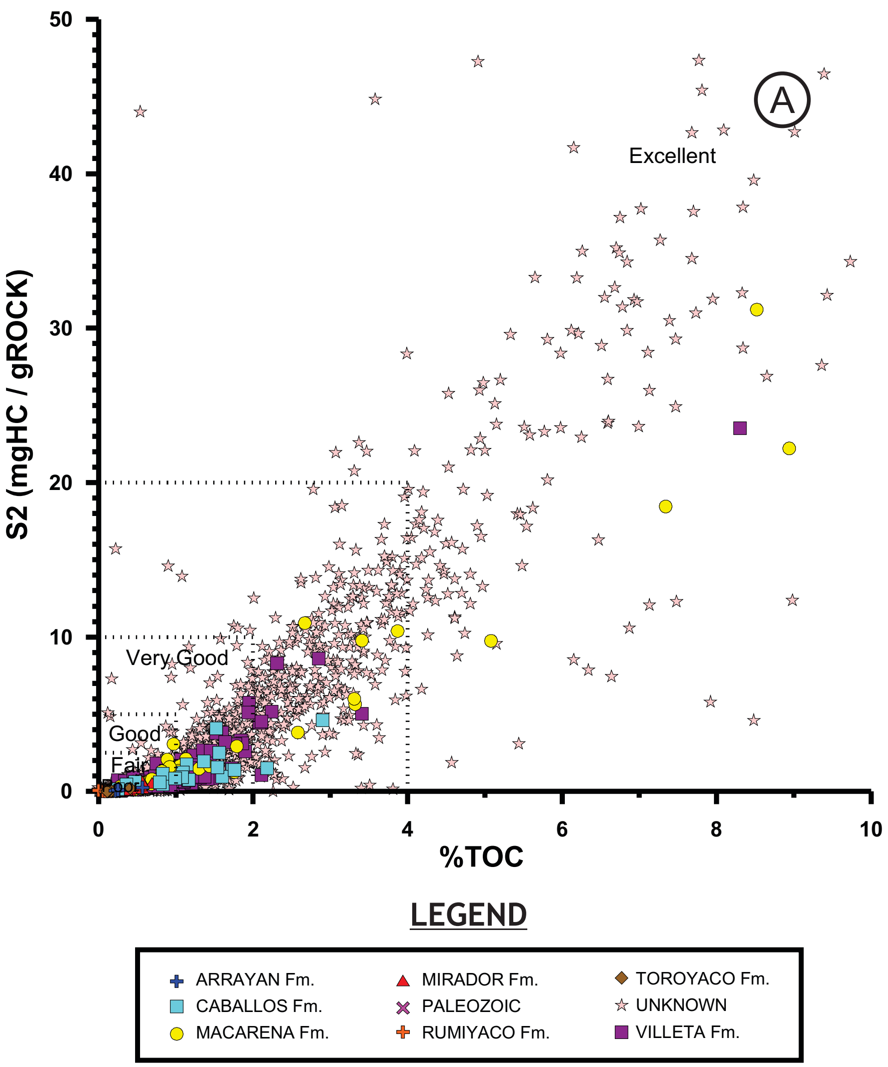


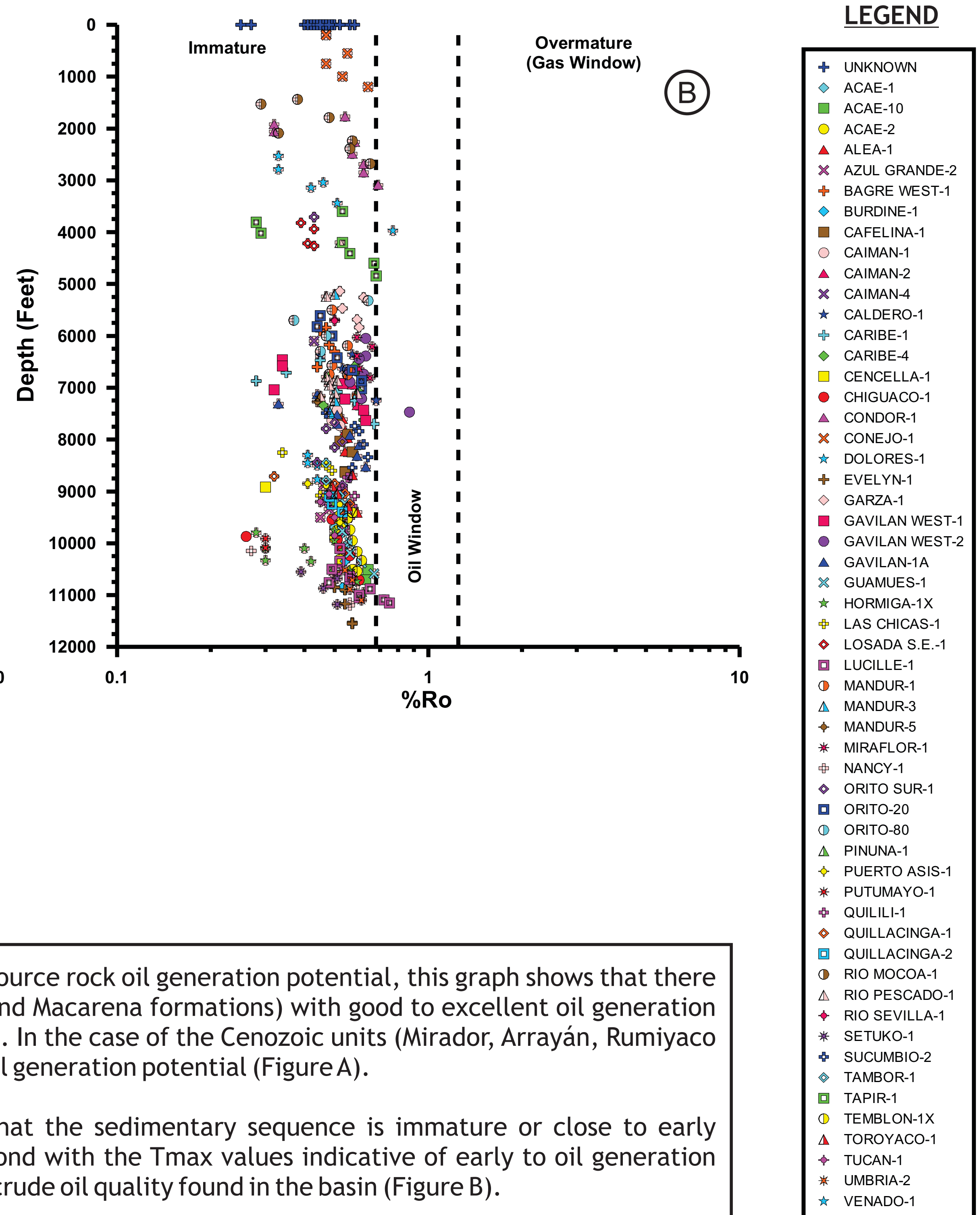
- The data obtained from pyrolysis Rock-Eval of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Cretaceous Caballos, Villeta and Macarena formations have good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock). Taking into account that these units are deeply buried in the basin, the poor generation values obtained from some samples could reflect the depletion effect caused by the high thermal maturity of these rocks. The data also indicate that the Cenozoic rocks (Mirador, Rumiyaco and Toroyaco formations) all have poor generation potential (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cretaceous Caballos, Villeta and Macarena formations have type II oil-prone kerogen. There are also samples from these formations with type III gas-prone characteristics. In the case of the Cenozoic units (Mirador, Arrayán, Rumiyaco and Toroyaco formations) their samples are indicative of type III gas-prone kerogen to type IV kerogen. The Paleozoic samples have very low HI values and correspond mainly with type IV kerogen (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples from the Cretaceous to Cenozoic units mentioned, have reached early maturity to oil generation peak conditions in the basin (Figure C).

Source Rock Characterization





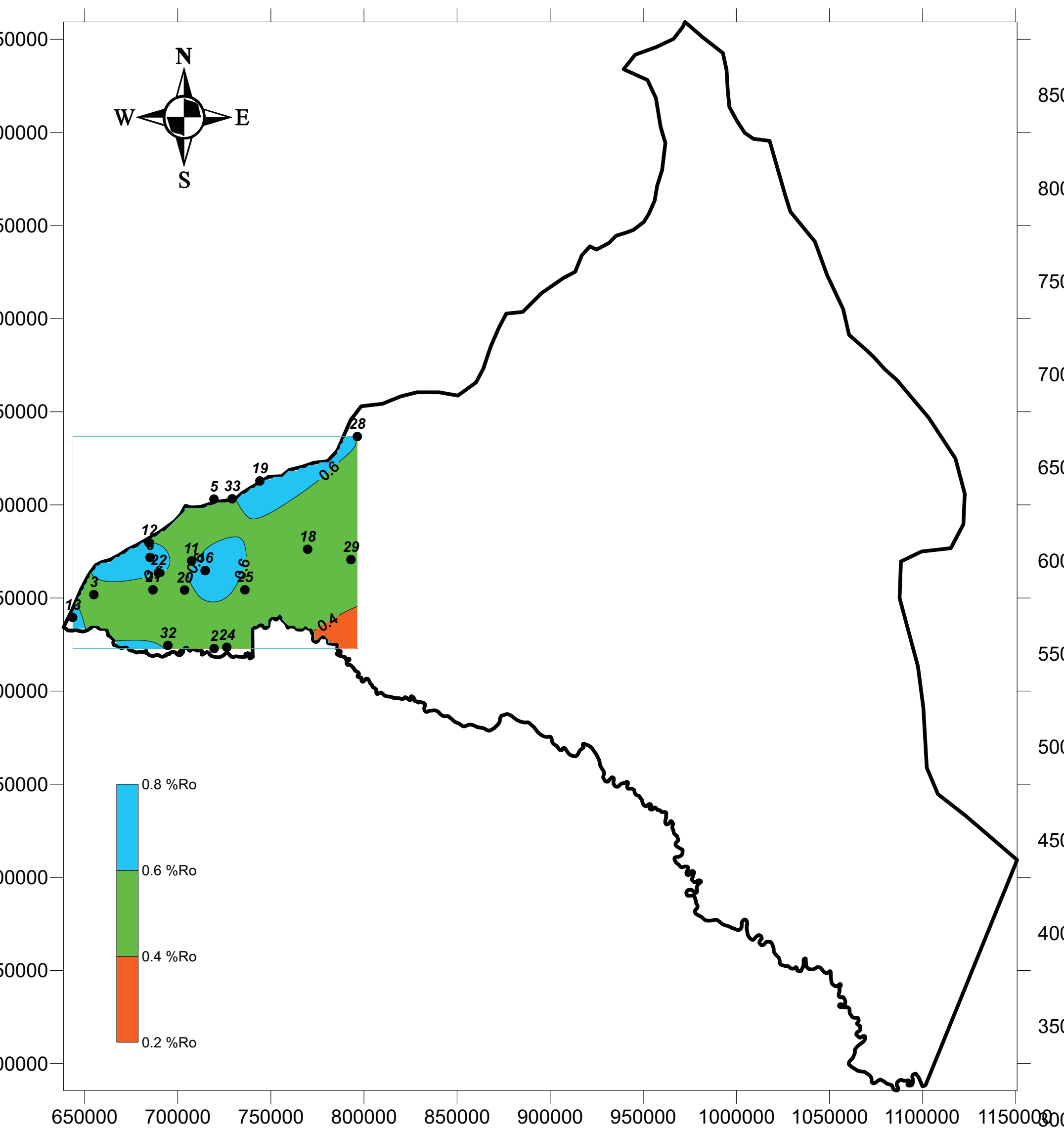
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from Cretaceous units (Caballos, Villeta and Macarena formations) with good to excellent oil generation potential (S2 up to 50 mg HC/g rock and % TOC up to 9). In the case of the Cenozoic units (Mirador, Arrayán, Rumiyaco and Toroyaco formations) their samples indicate poor oil generation potential (Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence is immature or close to early maturity in the basin. This behavior does not correspond with the Tmax values indicative of early to oil generation peak, and would not explain the oil accumulations and crude oil quality found in the basin (Figure B).

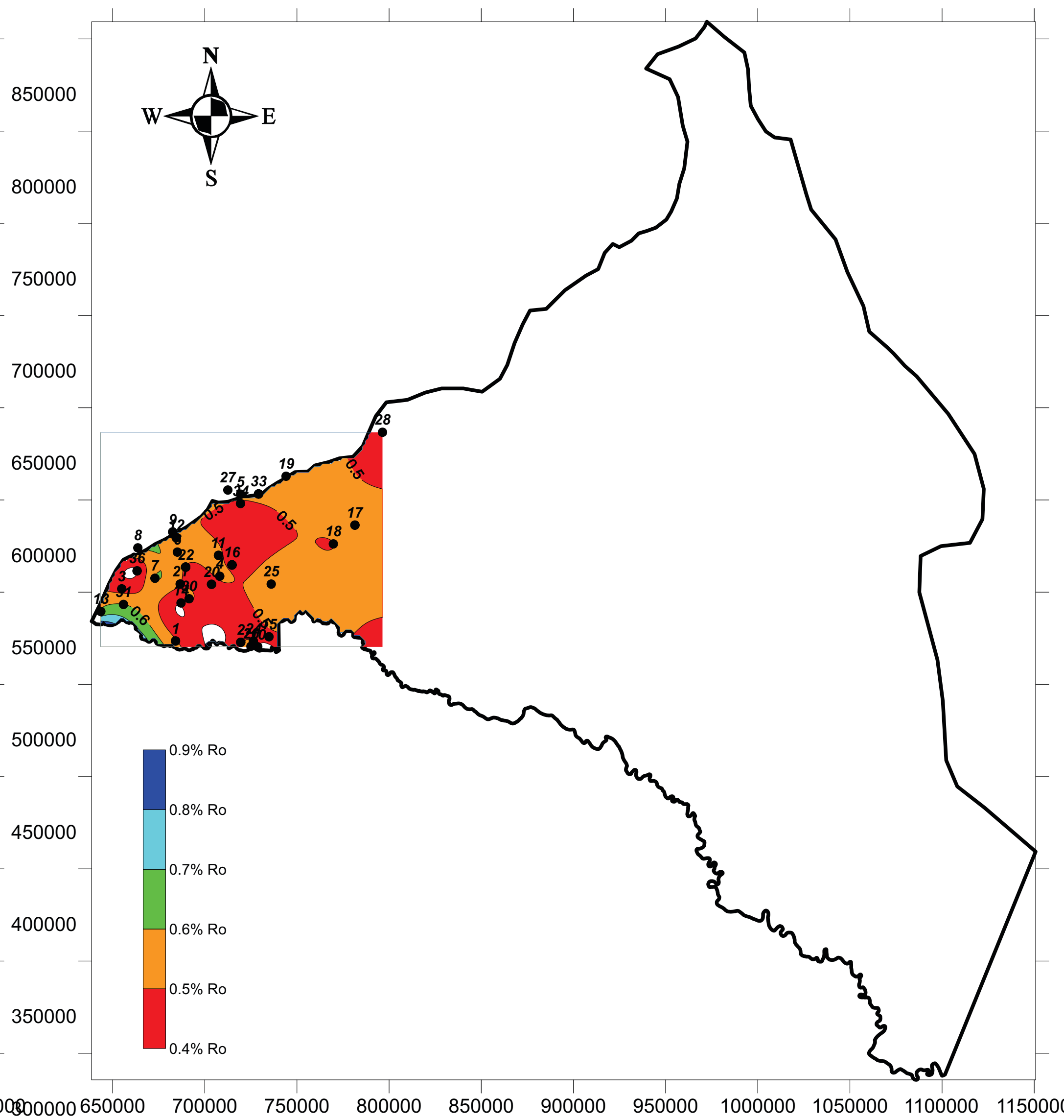
-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Cretaceous rocks of the Caballos, Villeta and Macarena formations. The Cenozoic rocks of the Mirador, Arrayán, Rumiyaco and Toroyaco formations have poor oil generation potential. Tmax maturity data indicates that the Cretaceous oil-prone formations are mature and the sources for the hydrocarbons in the basin.

Source Rock Quality and Maturity Maps

Vitrinite Reflectance (%Ro)



Caballos Fm.



Villeta Fm.

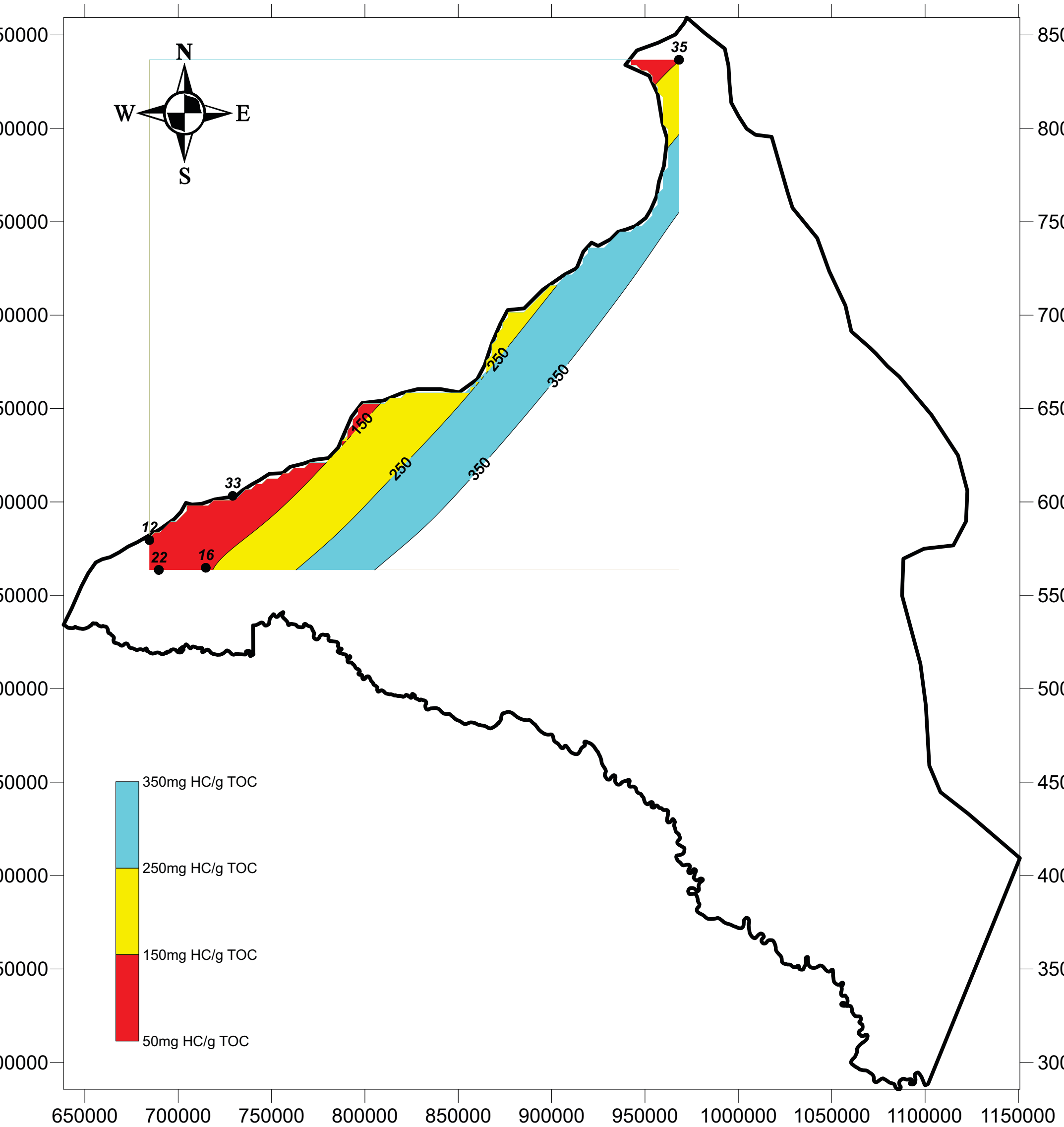
LEGEND

1. ACAE-2	7. CARIBE-4	13.GAVILAN WEST-2	19. MIRAFLOR-1	25. QUILILI-1	31. SUCUMBIO-2
2. AZUL GRANDE-2	8. CONDOR-1	14. HORMIGA-1X	20. NANCY-1	26. QUILLACINGA-1	32. TEMBLÓN-1X
3. BAGRE WEST-1	9. CONEJO-1	15. LAS CHICAS-1	21. ORITO SUR-1	27. RÍO MOCOA-1	33. TOROYACO-1
4. BURDINE-1	10. DOLORES-1	16. LUCILLE-1	22. ORITO-20	28. RÍO PESCADO-1	34. TUCÁN-1
5. CAFELINA-1	11. EVELYN-1	17. MANDUR-1	23. PINUNA-1	29. RÍO SEVILLA-1	35. URIBE-1
6. CALDERO-1	12. GARZA-1	18. MANDUR-3	24. PUERTO ASIS-1	30. SETUKO-1	36. VENADO-1

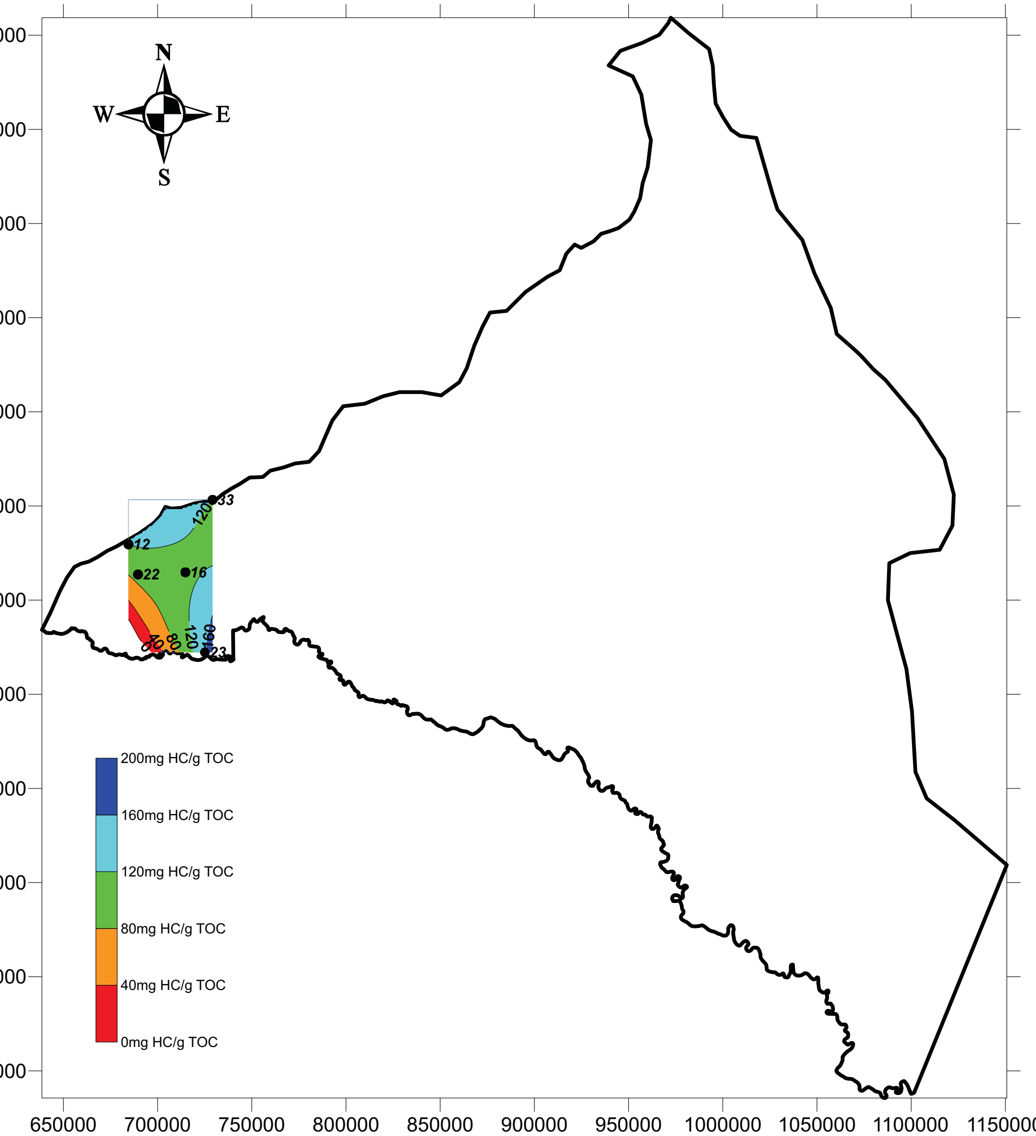
Map datum: Magna Sirgas
Coord. origin: Bogotá

Source Rock Quality and Maturity Maps

Hydrogen Index



Caballos Fm.



Villeta Fm.

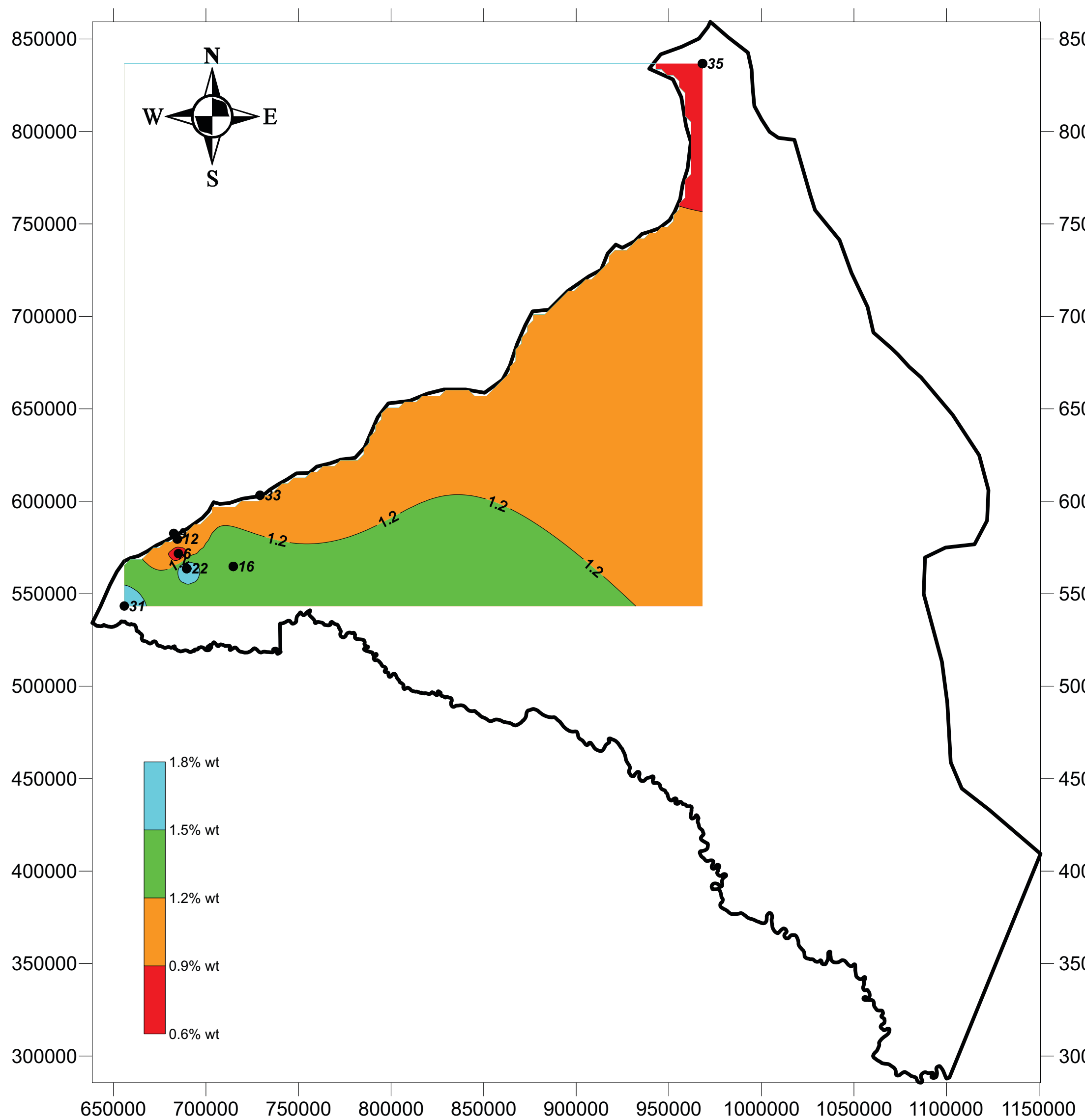
LEGEND

1. ACAE-2	7. CARIBE-4	13.GAVILAN WEST-2	19. MIRAFLOR-1	25. QUILILI-1	31. SUCUMBIO-2
2. AZUL GRANDE-2	8. CONDOR-1	14. HORMIGA-1X	20. NANCY-1	26. QUILLACINGA-1	32. TEMBLÓN-1X
3. BAGRE WEST-1	9. CONEJO-1	15. LAS CHICAS-1	21. ORITO SUR-1	27. RÍO MOCOA-1	33. TOROYACO-1
4. BURDINE-1	10. DOLORES-1	16. LUCILLE-1	22. ORITO-20	28. RÍO PESCADO-1	34. TUCÁN-1
5. CAFELINA-1	11. EVELYN-1	17. MANDUR-1	23. PINUNA-1	29. RÍO SEVILLA-1	35. URIBE-1
6. CALDERO-1	12. GARZA-1	18. MANDUR-3	24. PUERTO ASIS-1	30. SETUKO-1	36. VENADO-1

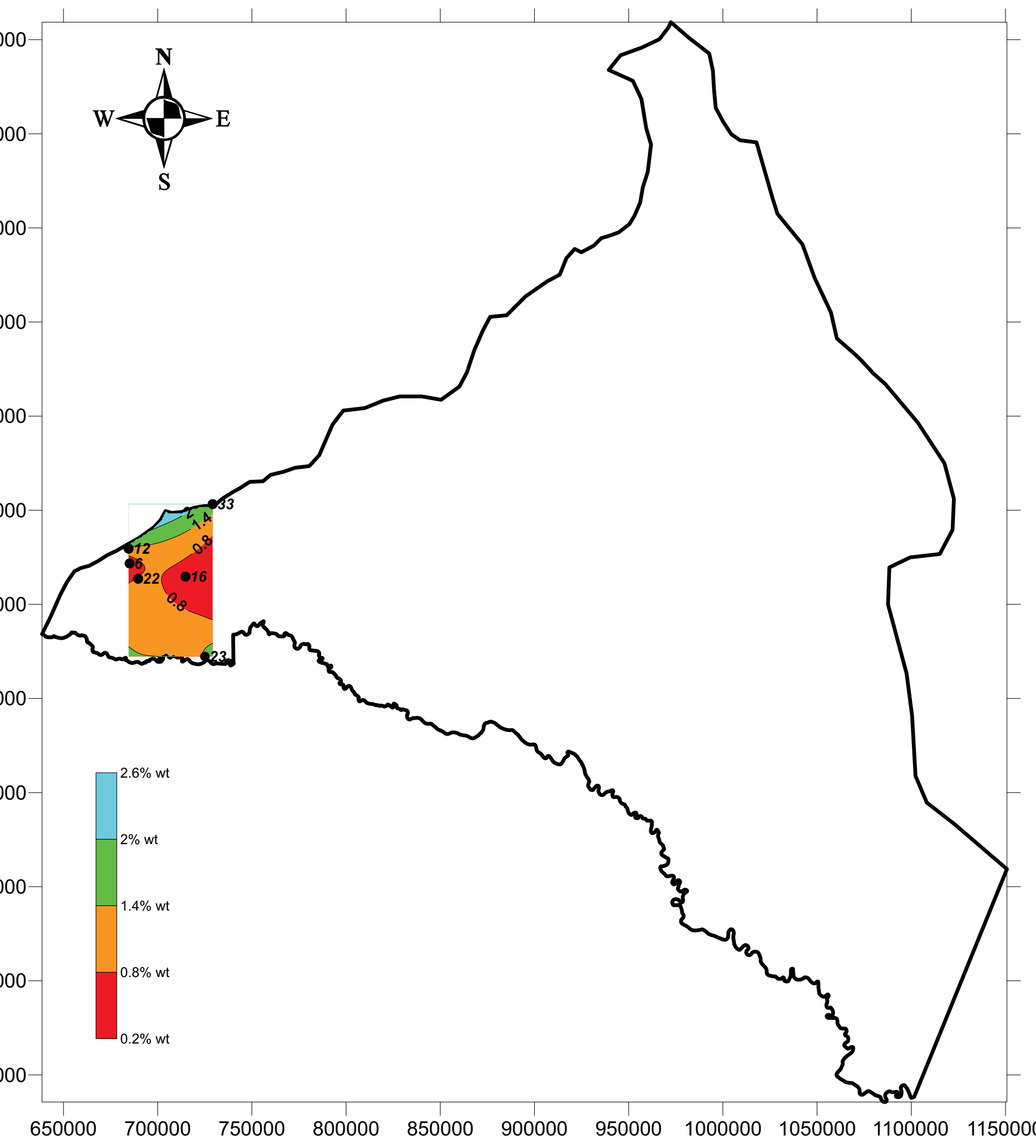
Map datum: Magna Sirgas
Coord. origin: Bogotá

Source Rock Quality and Maturity Maps

Organic Matter Content (TOC)



Caballos Fm.



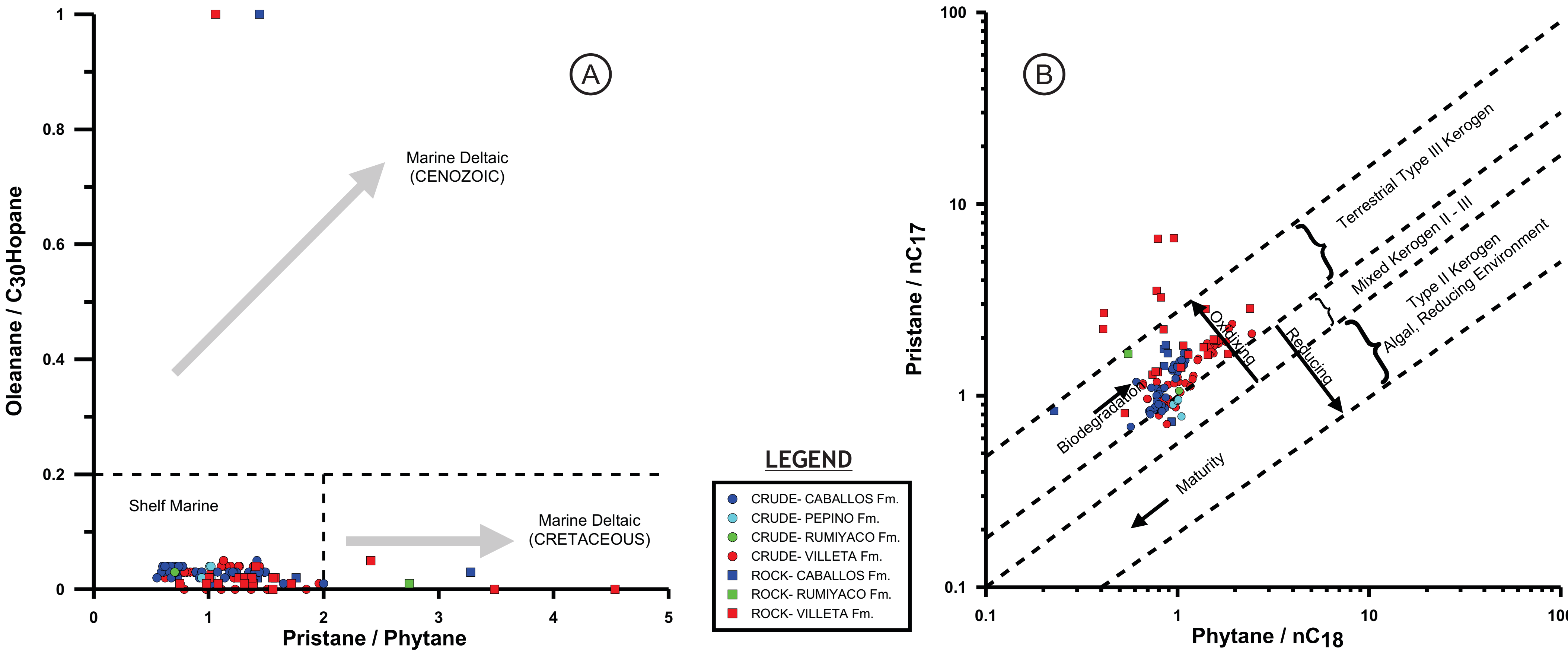
Villeta Fm.

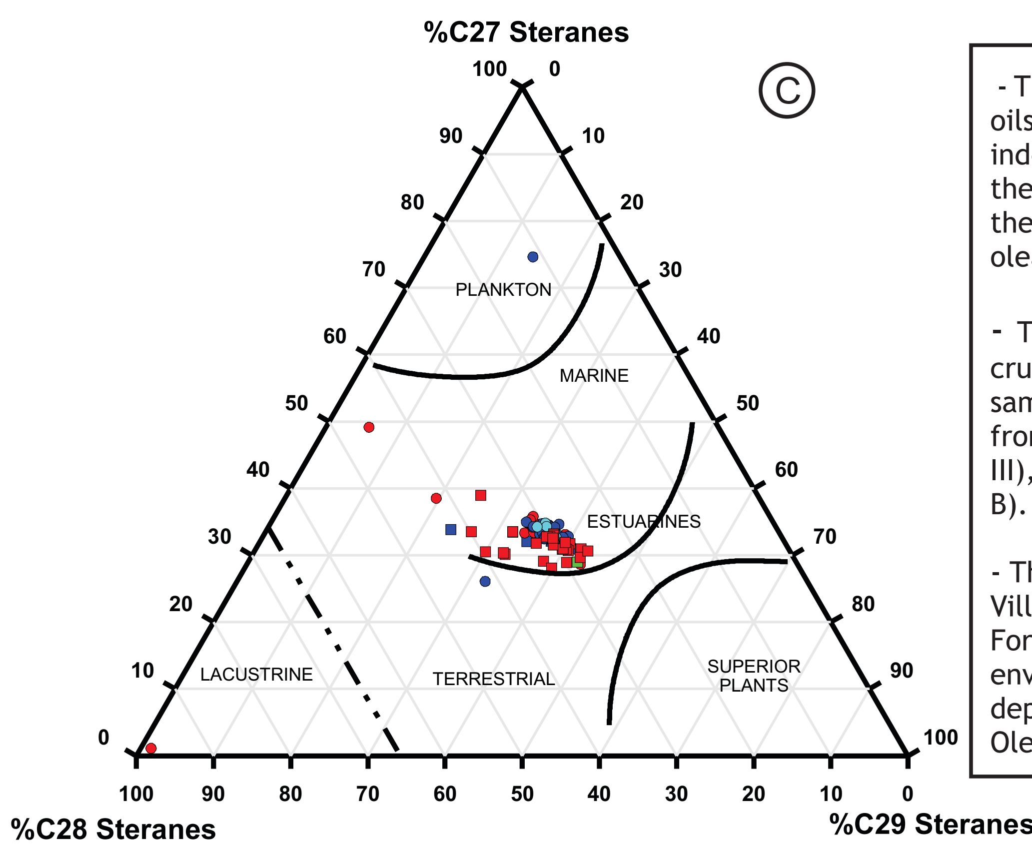
LEGEND

1. ACAE-2	7. CARIBE-4	13.GAVILAN WEST-2	19. MIRAFLOR-1	25. QUILILI-1	31. SUCUMBIO-2
2. AZUL GRANDE-2	8. CONDOR-1	14. HORMIGA-1X	20. NANCY-1	26. QUILLACINGA-1	32. TEMBLÓN-1X
3. BAGRE WEST-1	9. CONEJO-1	15. LAS CHICAS-1	21. ORITO SUR-1	27. RÍO MOCOA-1	33. TOROYACO-1
4. BURDINE-1	10. DOLORES-1	16. LUCILLE-1	22. ORITO-20	28. RÍO PESCADO-1	34. TUCÁN-1
5. CAFELINA-1	11. EVELYN-1	17. MANDUR-1	23. PINUNA-1	29. RÍO SEVILLA-1	35. URIBE-1
6. CALDERO-1	12. GARZA-1	18. MANDUR-3	24. PUERTO ASIS-1	30. SETUKO-1	36. VENADO-1

Map datum: Magna Sirgas
Coord. origin: Bogotá

Petroleum Systems (Crude-Rock Correlations)



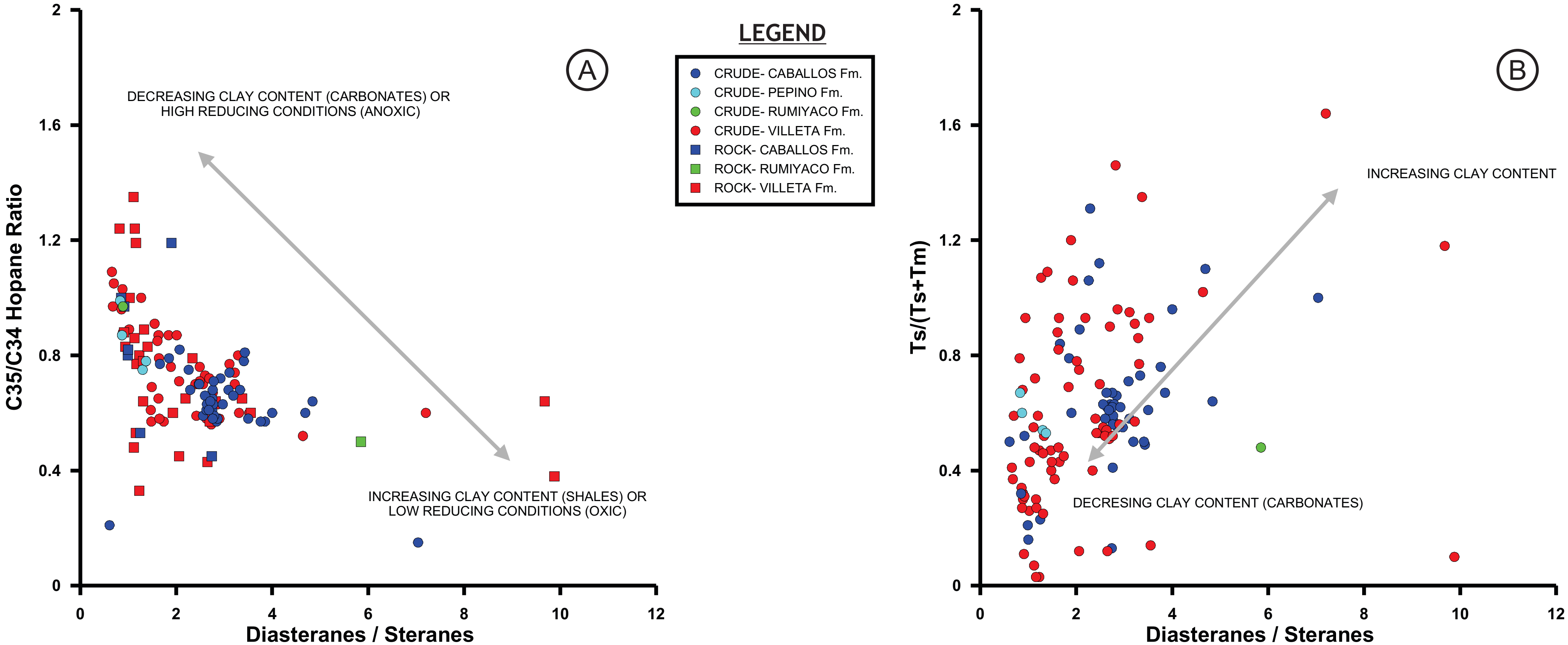


- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that oils from the Caballos, Villeta, Pepino and Rumiyaco reservoirs have low oleanane index values (<0.2) and Pr/Ph values (<2), and correlate well with rock extracts from the Villeta and Caballos formations, suggesting that these units are the sources for the hydrocarbons found in those reservoirs at the basin. Additionally the low oleanane values correlate well with the Cretaceous age of the sources (Figure A).

- The Phytane/nC18 vs Pristane/nC17 graph shows good correlation between the crude oils found in the Caballos, Villeta and Pepino reservoirs with rock extracts from samples of the Caballos and Villeta formations. Indicating that the oils have origin from terrestrial organic matter and to a minor extent from mixed kerogen (type II-III), but additionally that the crudes and rocks have similar thermal maturities (Figure B).

- The steranes ternary plot shows good correlation of crude oils from the Caballos, Villeta, Pepino and Rumiyaco reservoirs with rock extracts from Caballos and Villeta Formations, and that these rocks were deposited in an estuarine to marine environment which is conformable with terrigenous input and shelf marine depositional environment indicated by other parameters (c.e. Pristane/Phytane, Oleanane Index, Homohopanes Index, Pristane/ nC17) (Figure C).

Petroleum Systems (Crude-Rock Correlations)



- The Homohopanes Index (C35/C34 Hopane ratio) vs diasteranes/steranes graph shows good correlation between the crude oils from the Caballos, Villeta and Pepino reservoirs with rock extracts from the Caballos and Villeta formations, indicating also that these crudes were formed from rocks deposited in suboxic environments with variable clay content (Figure A).

- The Ts/(Ts+Tm) vs diasteranes/steranes graph shows good correlation between crude oils from the Caballos, Villeta and Pepino formations with rock extracts from the Caballos and Villeta formations. In this graph there is better correlation of Caballos formation crudes with Villeta formation extracts than with Caballos formation extracts, and of Villeta formation oils with Caballos and Villeta extracts. Additionally this graph suggests that oils were formed from clay-poor rocks.

Crude - Rock correlations from samples at the basin suggest the following:

- Good correlation between crudes from the Caballos, Villeta and Pepino reservoirs and extracts from the Villeta and Caballos formations (low diasteranes/steranes, low Ts/Tm, C35/C34 hopane ratio < 1, low oleanane index, Pristane/Phytane < 2, and predominance of C27/C29 steranes).

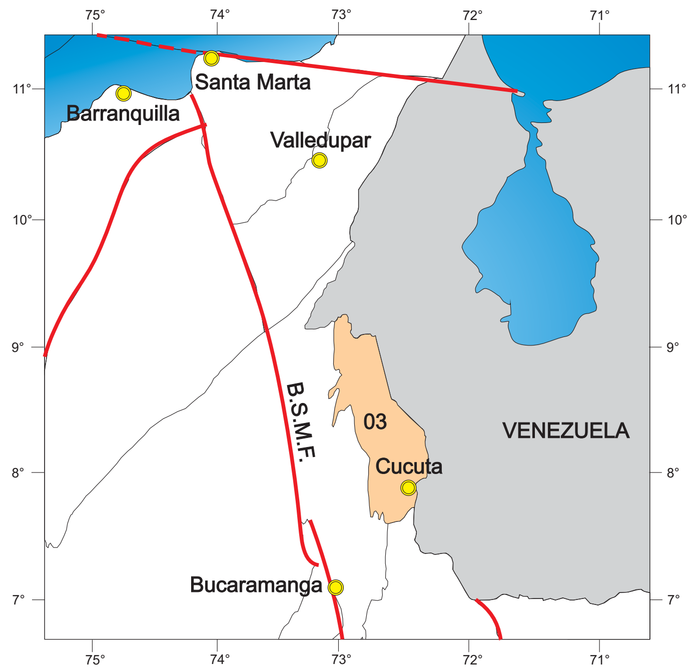
- This indicates the presence of several active petroleum systems at the basin named as follows: Caballos (!), Villeta - Caballos (!), Villeta (!), Villeta - Pepino (!) and Caballos - Pepino (!).

CATATUMBO BASIN

Generalities
Wells and Seeps
Crude Oil Quality
Depositional Environments
Chromatography
Source Rock Characterization
Source Rock Quality and Maturity Maps
Gas Characterization

Generalities

CATATUMBO BASIN
LOCATION AND BOUNDARIES



B.S.M.F. Bucaramanga-Santa Marta Fault System

From Barrero et al., 2007

BOUNDARIES

North: Geographic Border with Venezuela

East: Geographic Border with Venezuela

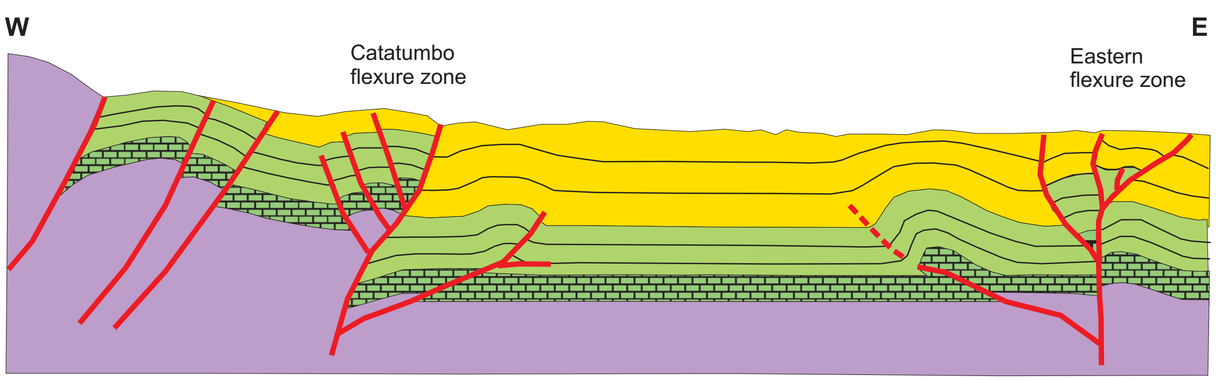
South: Eastern Cordillera Cretaceous rocks

West: Santander Massif igneous and metamorphics

The source rock geochemical information interpreted for the Catatumbo Basin includes %TOC and Rock-Eval Pyrolysis data from 1195 samples taken in 33 wells; additionally 343 organic petrography samples from 21 wells were interpreted.

Crude oil information from 146 bulk analysis samples, 235 liquid chromatography samples, 275 gas chromatography samples, 242 biomarker samples and 170 isotopes samples were also interpreted.

SCHEMATIC CROSS SECTION
CATATUMBO BASIN



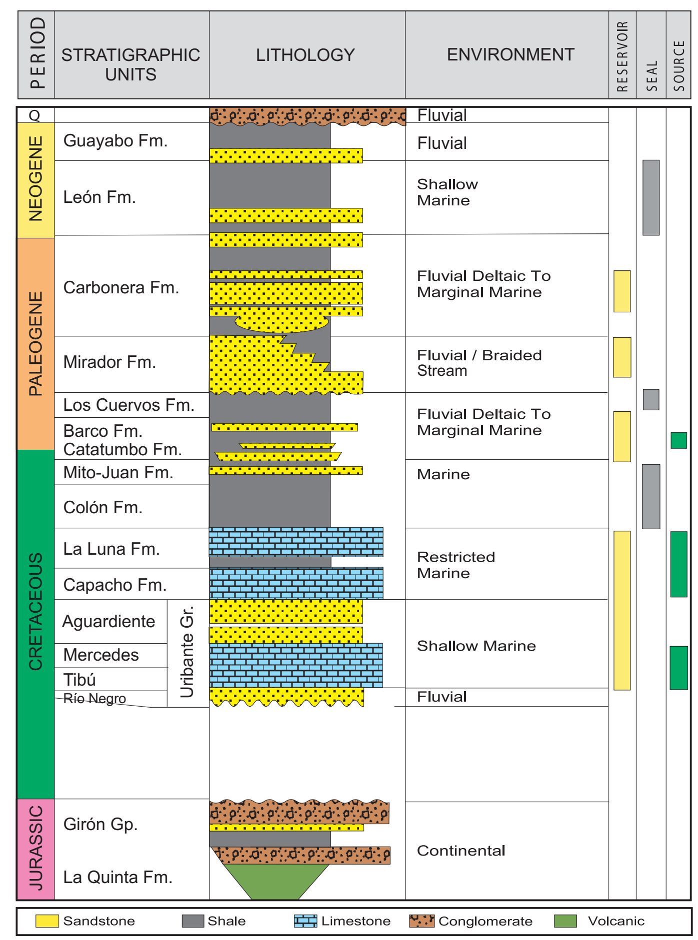
Modified from Yurewicz, et al., 1998

Color code according to the commission for the Geological Map of the World (2005)

Basement
Lower Cretaceous
Upper Cretaceous
Cenozoic

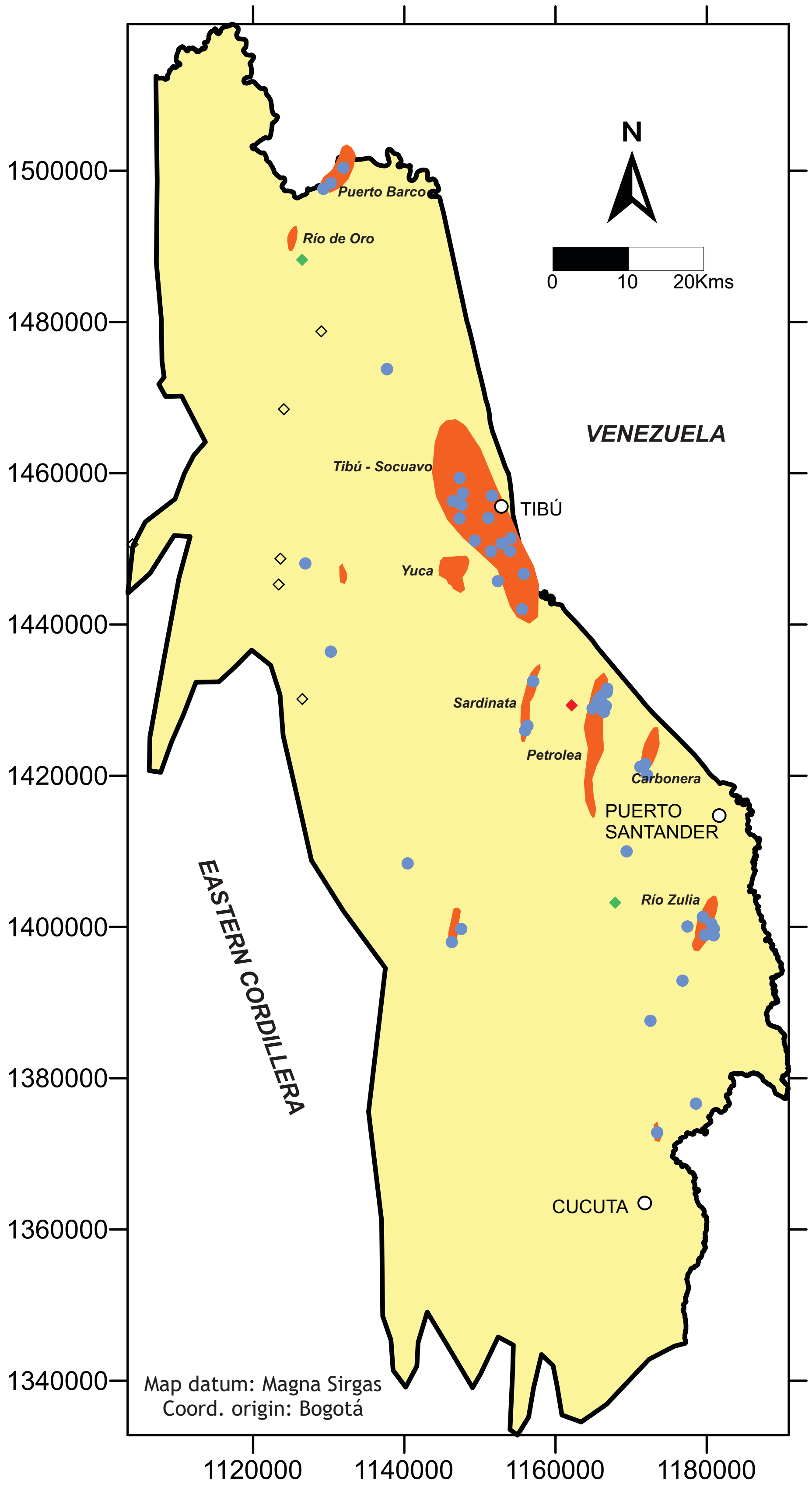
1000m
10Km
0
scale approx..

From Barrero et al., 2007



From Barrero et al, 2007

Wells and Seeps

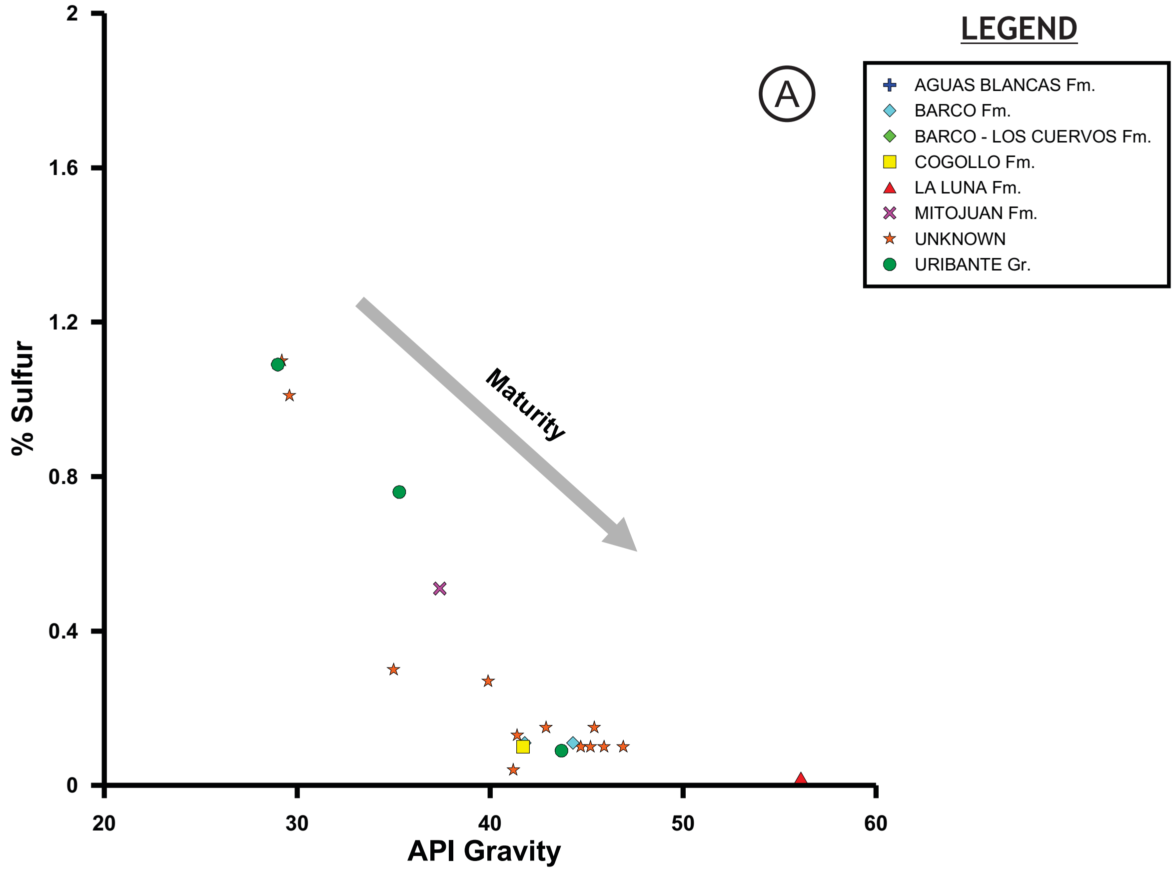


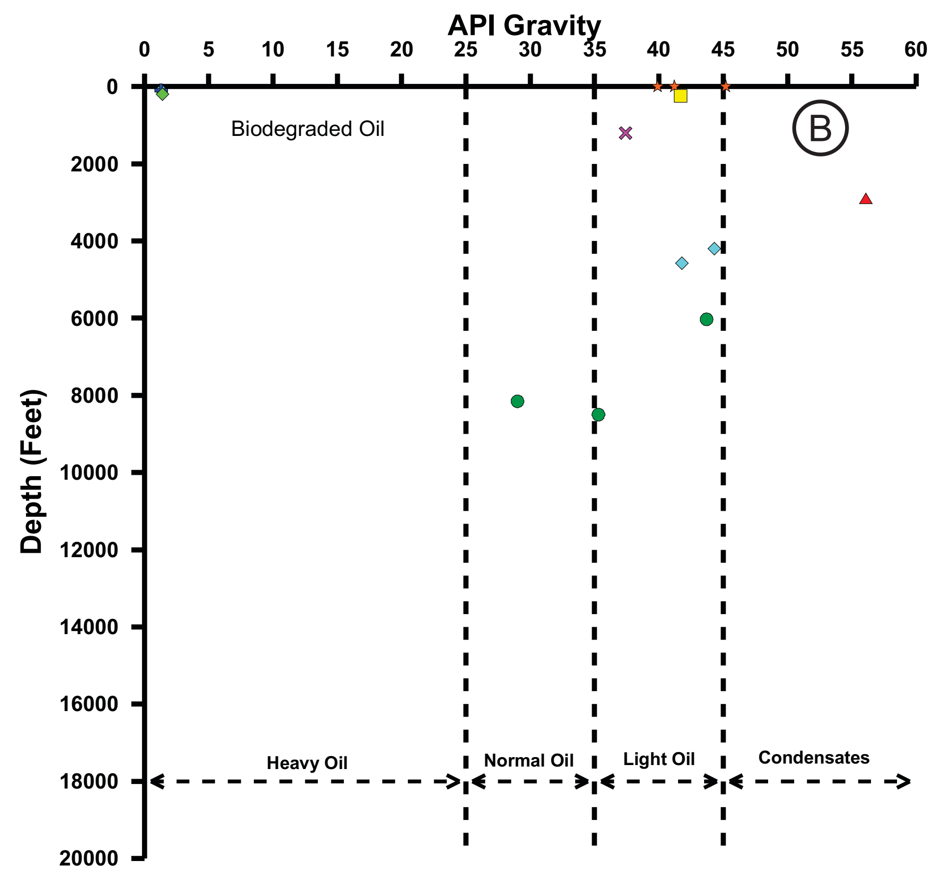
The number of wells and/or surface locations with geochemical information in the Catatumbo Basin is 56.

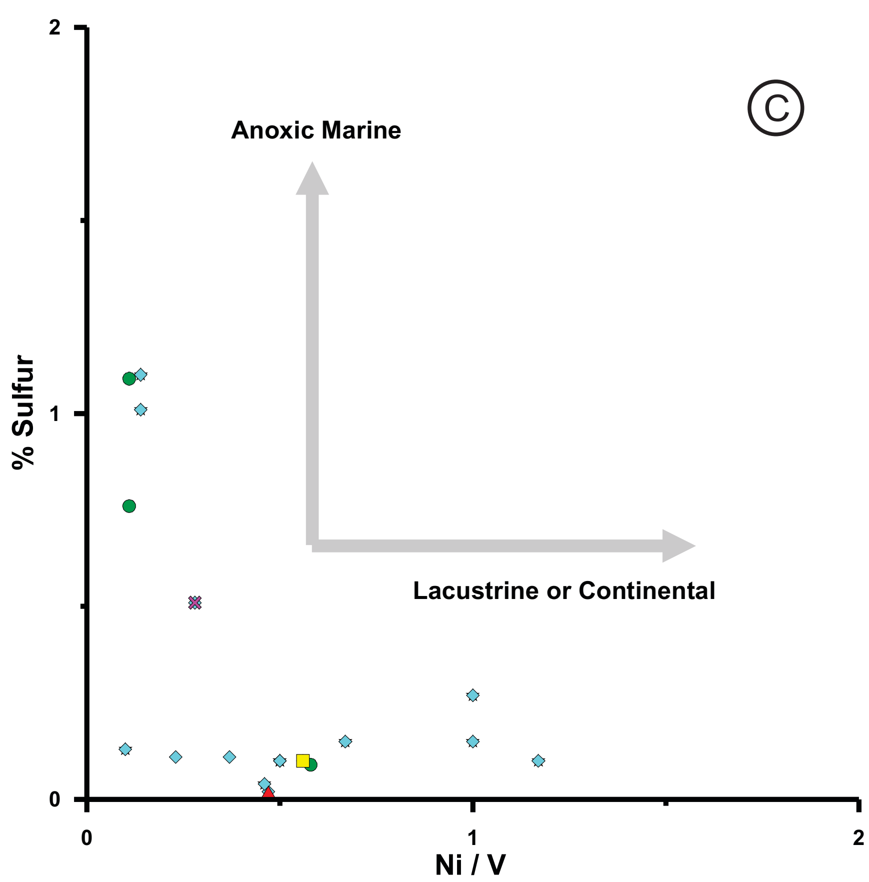
Seeps are located at the northwestern and eastern parts of the basin. Oil fields are mostly located to the east of the basin.

- Oil and gas fields
- Wells with geochemical information
- Oil seeps
- Gas seeps
- Undetermined seeps
- Cities/Towns

Crude Oil Quality







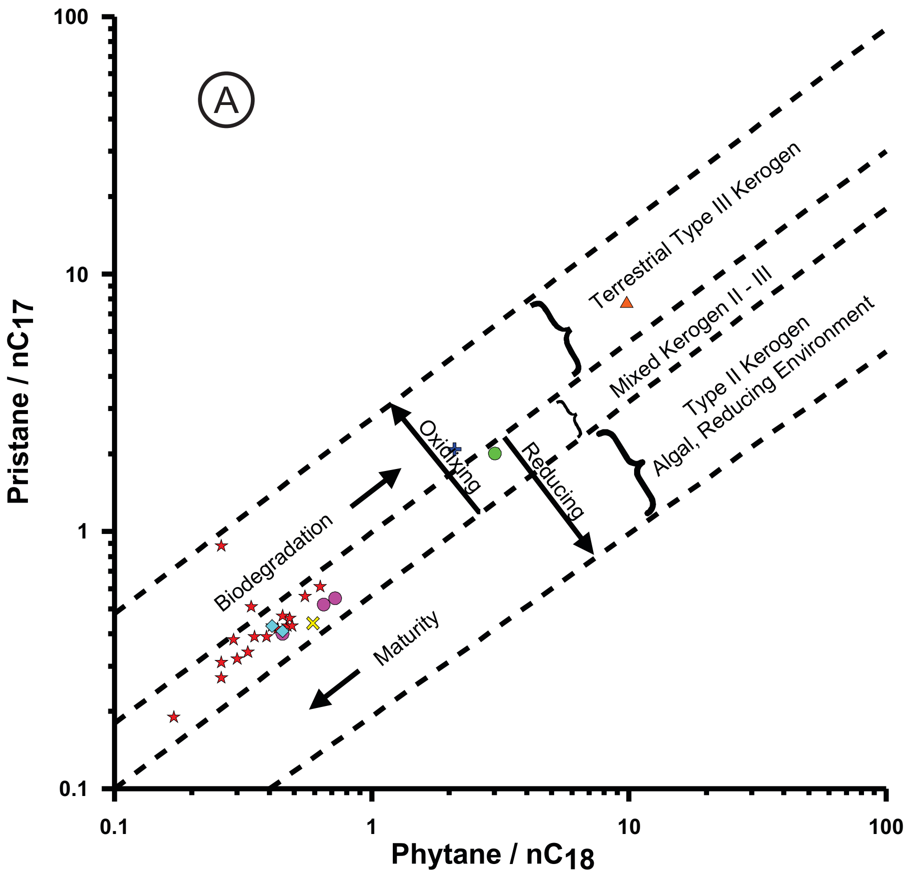
- Normal and light oils with API gravities ranging from 25° to 45° and sulfur content between 0 and 1.2% are present in the basin. There is a straight relationship between sulfur and API gravity, showing that high API gravity mature oils have low sulfur content regarding low API gravity less mature oils. (Figure A).

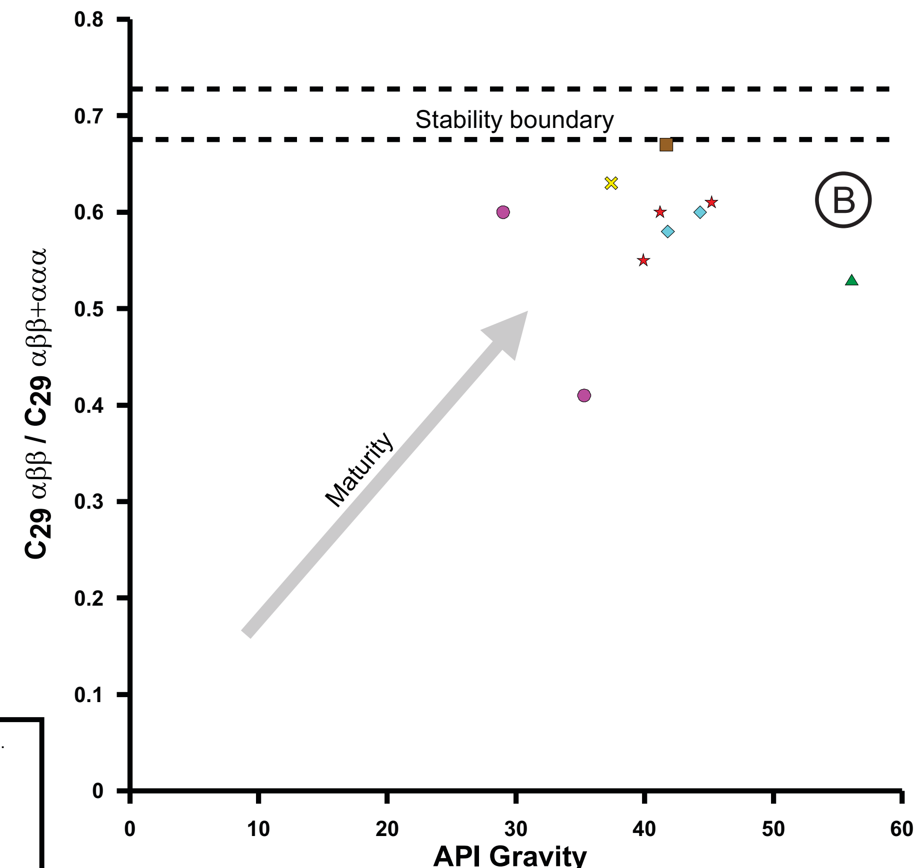
- There is no direct relationship between depth and crude oil quality, indicating that similar quality oils can be found at different stratigraphic levels, probably related to vertical migration in faulted reservoirs. But additionally there is the fact that different API gravity oils can be found at similar depths, reflecting different preservation (biodegradation) and/or thermal maturities (Figure B).

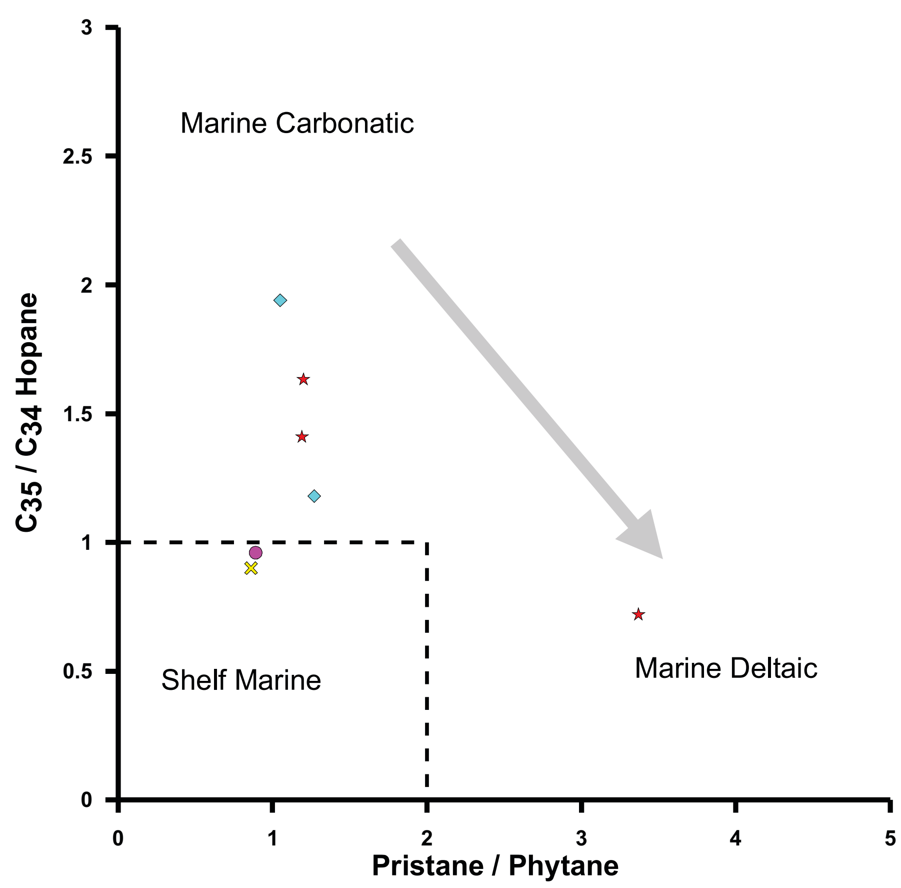
- The sulfur content of most crude oils is lower than 1%, and its Ni/V ratio below 1, suggesting that they are produced from rocks deposited in a marine suboxic to anoxic environment with marine organic matter input (Figure C).

-The oils of the Catatumbo Basin are of excellent quality, with high API gravity and low sulfur content and its high thermal evolution explains the high API gravity.

Depositional Environments





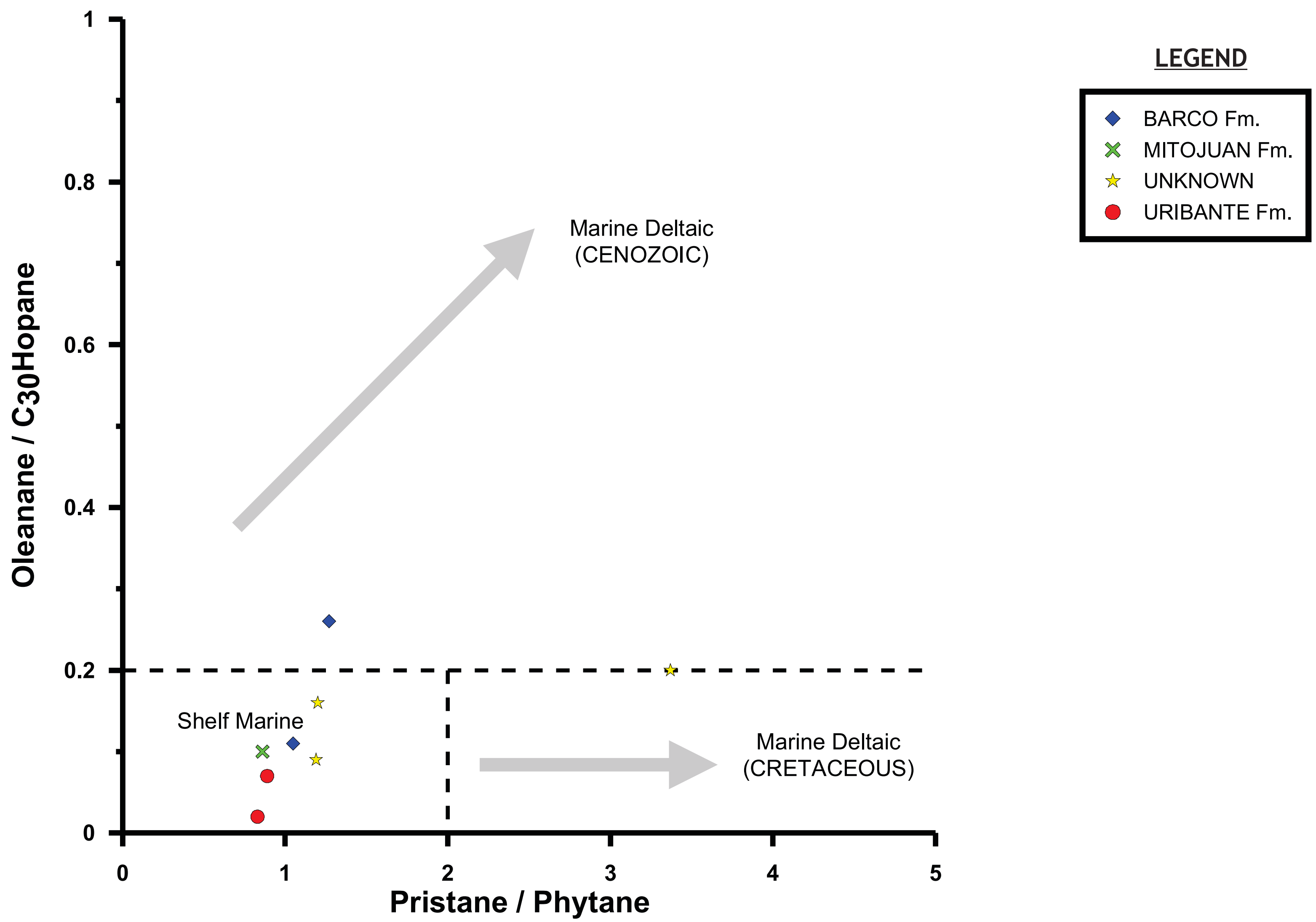


- The Phytane/nC18 vs Pristane/nC17 graph indicates that most of the oils have origin from mixed terrestrial-marine organic matter (Type II-III kerogens), have suffered low biodegradation and are thermally mature. There are some samples in the terrestrial kerogen range suggesting a source with terrestrial organic matter (Type III kerogen) deposited in more oxidizing conditions (Figure A).

- The API Gravity vs C29aBB/C29aBB+aaa graph, shows that oils with higher API gravity has higher C29 isomerization and close to equilibrium (stability boundary) as a result of their high thermal maturity (Figure B).

- The Pristane/Phytane vs C35/C34 Hopane (Homohopane index) graph shows that most oil samples have Pr/Ph values below 2 and C35/C34 Hopane above 1, indicating that these oils were generated from rocks with variable carbonatic input deposited in a shelf marine environment. Additionally there is one sample with low homohopane index but higher Pr/Ph values (>2) indicative of siliciclastic rocks deposited in marine deltaic environments (Figure C).

Depositional Environments



- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that most of the oils have low oleanane index values (<0.2) and Pr/Ph values (<2) which indicates that these oils are generated from source rocks deposited in shelf marine environments. There is one sample with low oleanane index values but high Pr/Ph (>2) indicating that these oils were generated from source rocks deposited in marine deltaic environments. The oleanane index has been also used as an age indicator of the source rock, with high oleanane values for oils generated in Cenozoic rocks and low oleanane values in oils from older rocks.

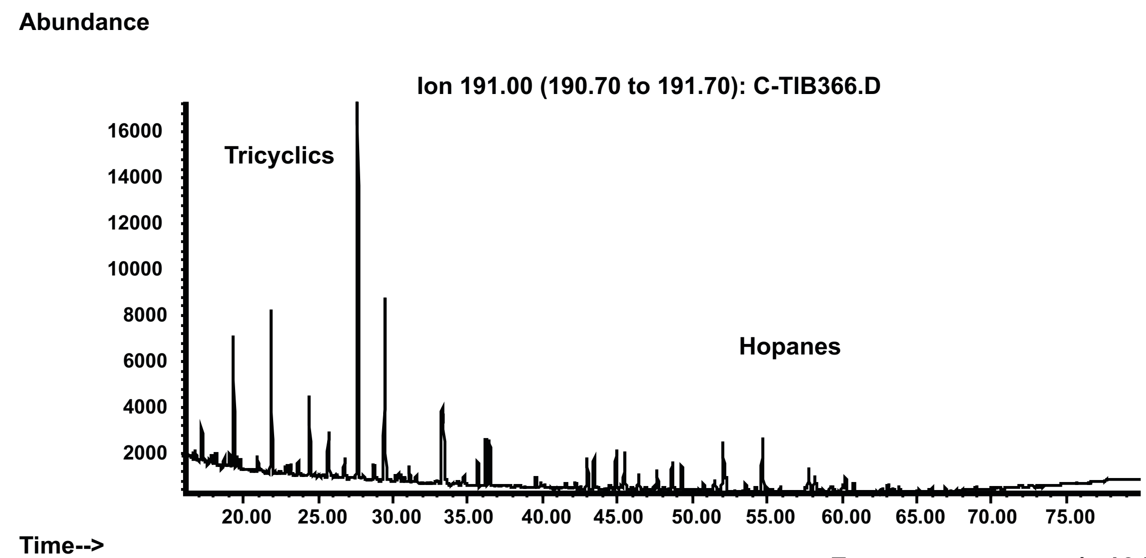
- In summary, the crude oils in the basin correspond predominantly with generating facies deposited in marine carbonatic and siliciclastic environments, with low terrestrial organic matter input. These rocks were deposited during the Cretaceous considering their low oleanane index values and the C35/C34 Hopane ratio above 1.0, suggests that the deposit environment of the source rocks was anoxic (carbonatic), which correspond to the La Luna and Capacho formations and the Uribante Group.

- These crude oils are of good quality with API gravities above 25° and sulfur content below 1% for most of them, and are well preserved (low biodegradation).

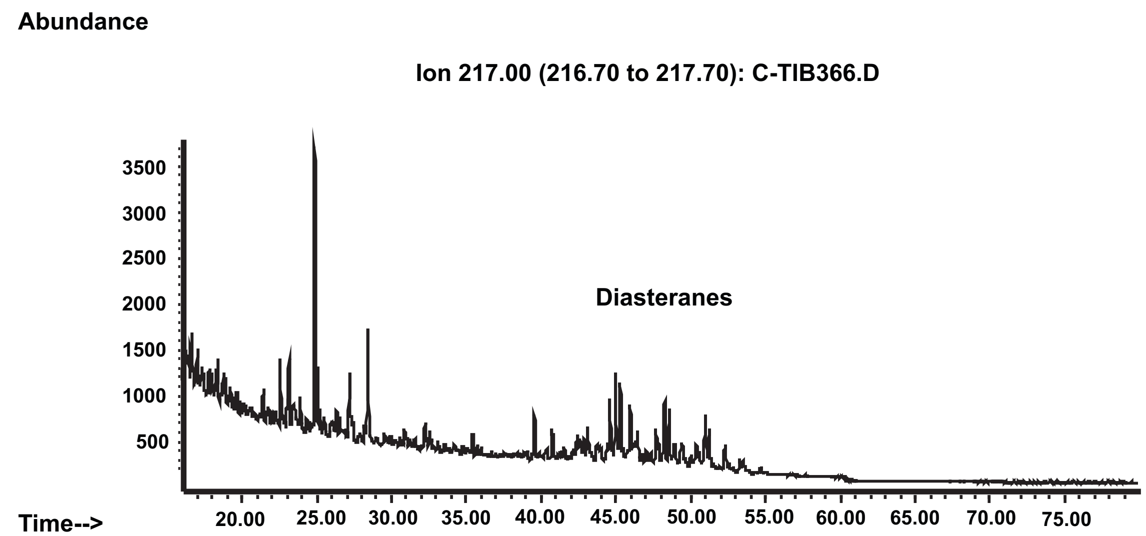
Chromatography

The crude oil of the Tibú-366 well is characterized by showing in gas chromatography, predominance of low molecular weight paraffins (high thermal maturity) and Pristane/Phytane ratio < 1.0.

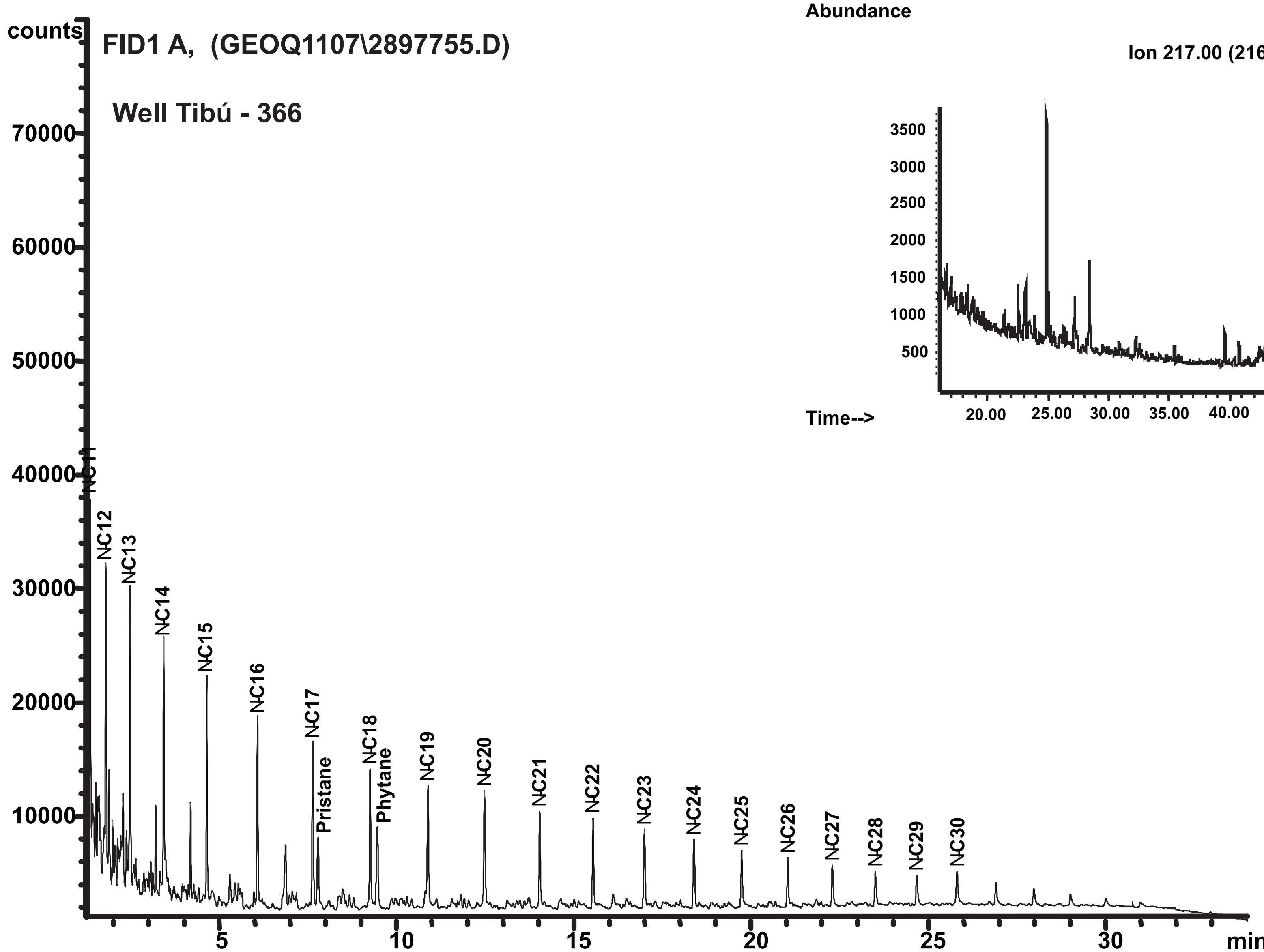
The high degree of thermal evolution of the oil has reduced the hopanes and steranes abundance and increased the tricyclics in the oil.



Fragmentogram m/z 191

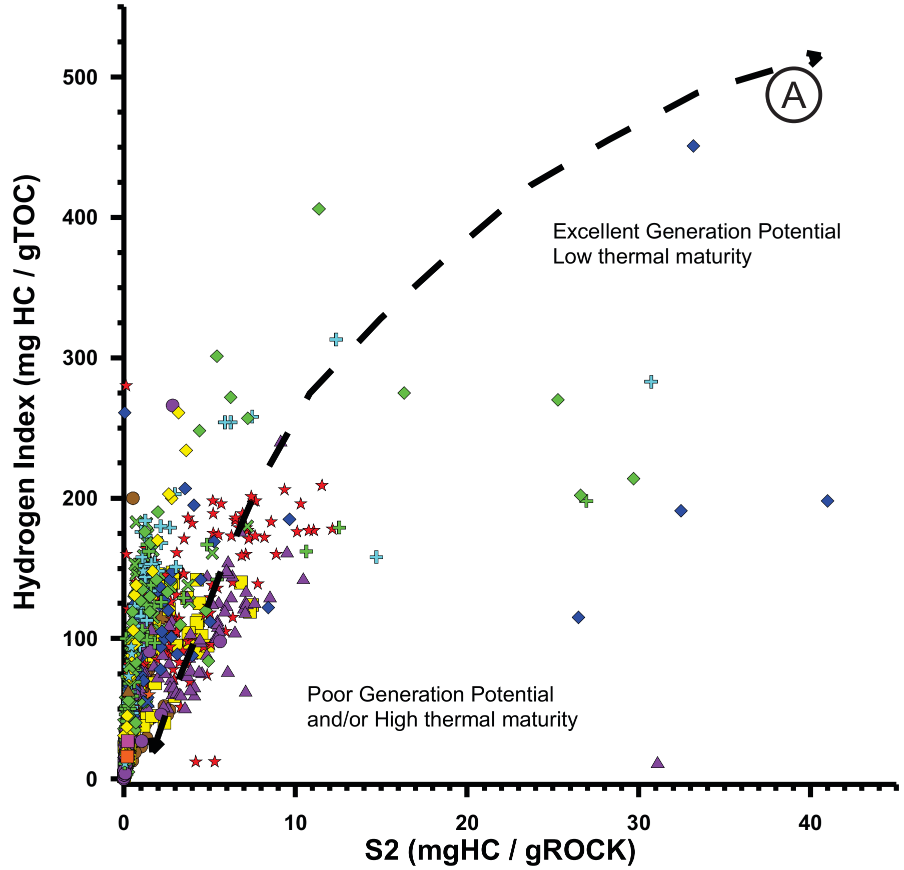


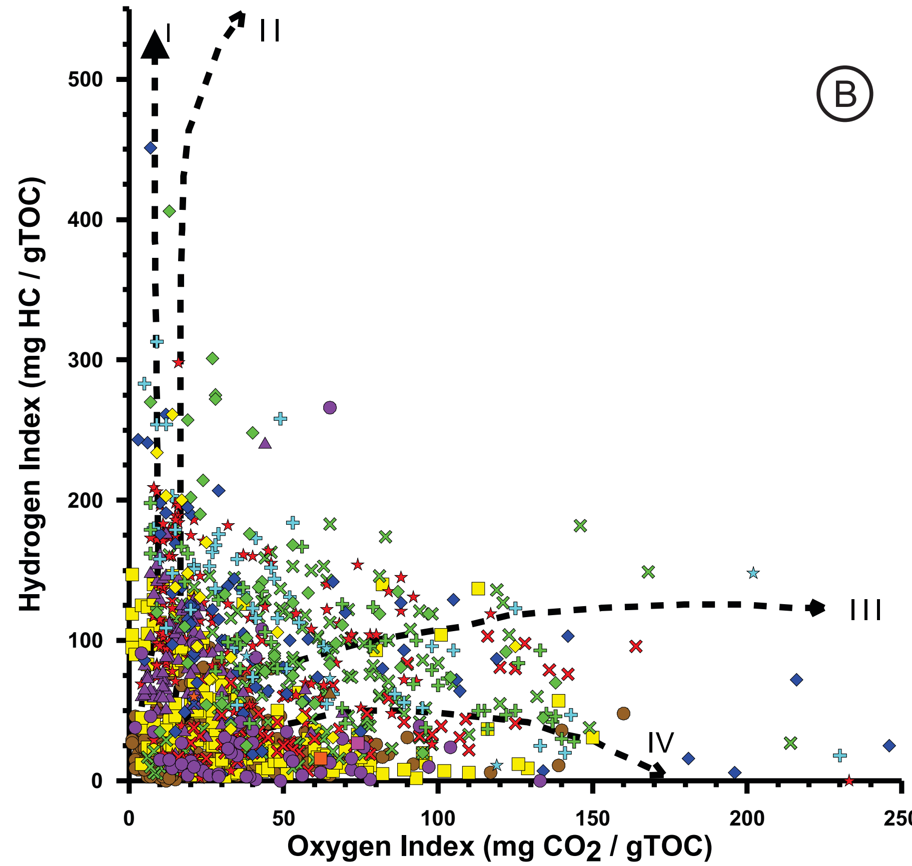
Fragmentogram m/z 217

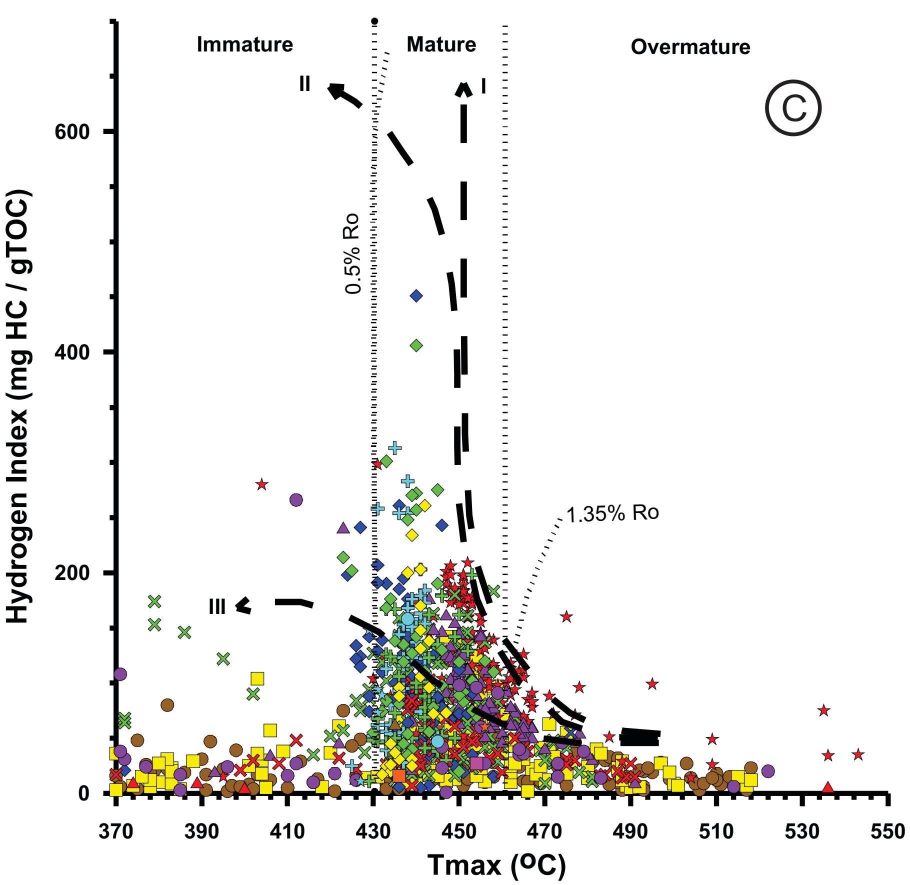


Chromatogram

Source Rock Characterization





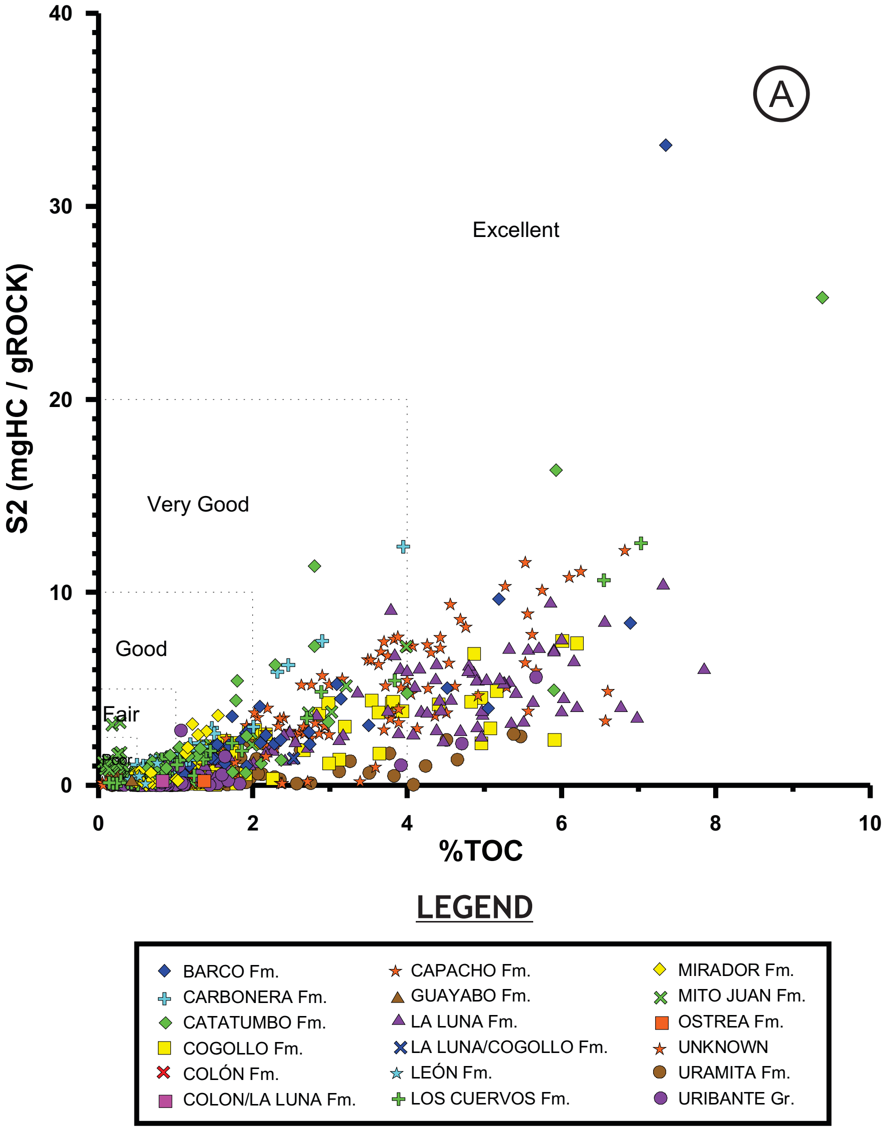


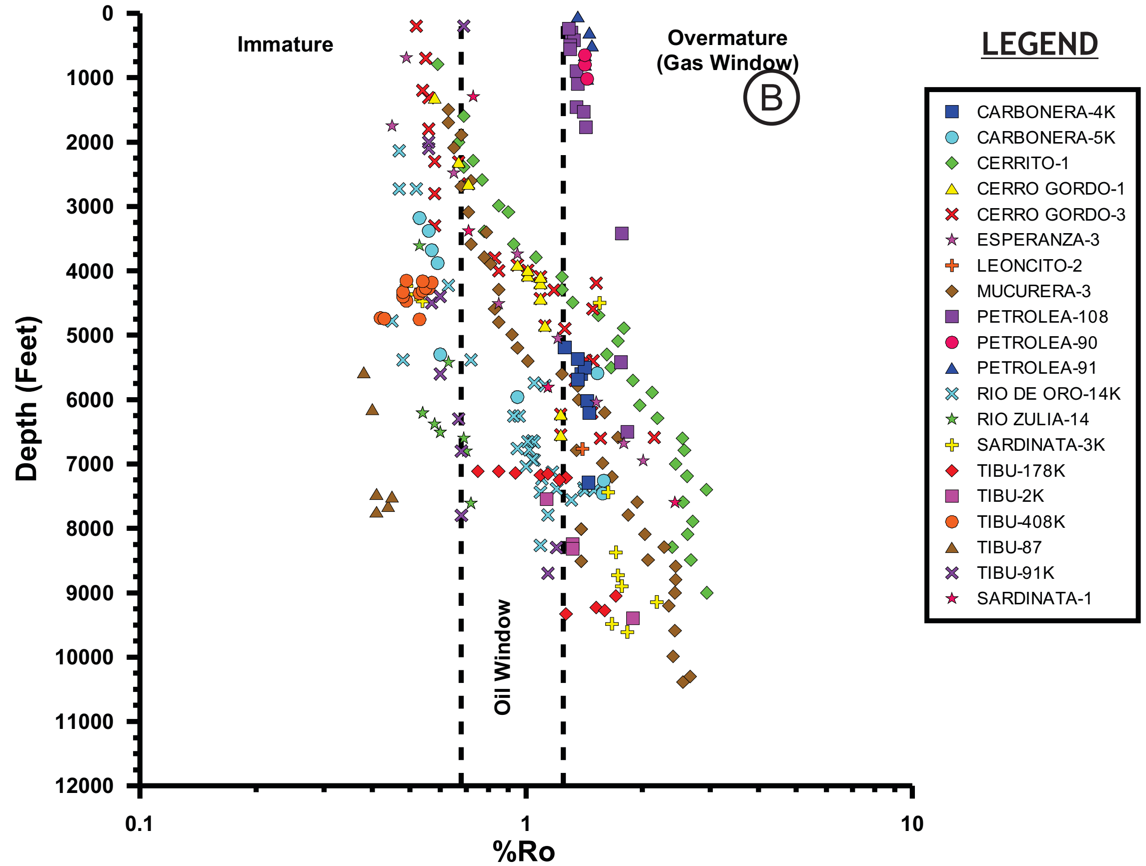
- The data obtained from pyrolysis of rock samples for Hydrogen Index (HI) and S2 peak, indicate that most samples have poor generation potential (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock), and there are few samples with good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock).In the case of the Cretaceous rocks should be considered that these units are deeply buried in the basin, and the poor generation values obtained from some samples could reflect the depletion effect caused by the high thermal maturity of these rocks. The data also indicate that most of the Cenozoic rocks (Mirador, Los Cuervos, León and Guayabo formations), have poor generation potential with the exception of the Barco and Carbonera formations which have samples with good generation potential (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cretaceous Uribante Group and La Luna, Capacho and Catatumbo formations, along with the Cenozoic Barco and Carbonera formations have type II oil-prone kerogen. Some samples of these units also have type III kerogen values. The Cretaceous Mito-Juan Formation and the Cenozoic units (Mirador and Los Cuervos formations) have samples predominantly of type III gas-prone kerogen to type IV kerogen. (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples from the Cretaceous to Cenozoic units mentioned, have reached early maturity to overmature conditions in the basin, being the Cretaceous units more mature than the Cenozoic units, explaining the high thermal maturity indicated by the oils found in the basin (Figure C).

Source Rock Characterization





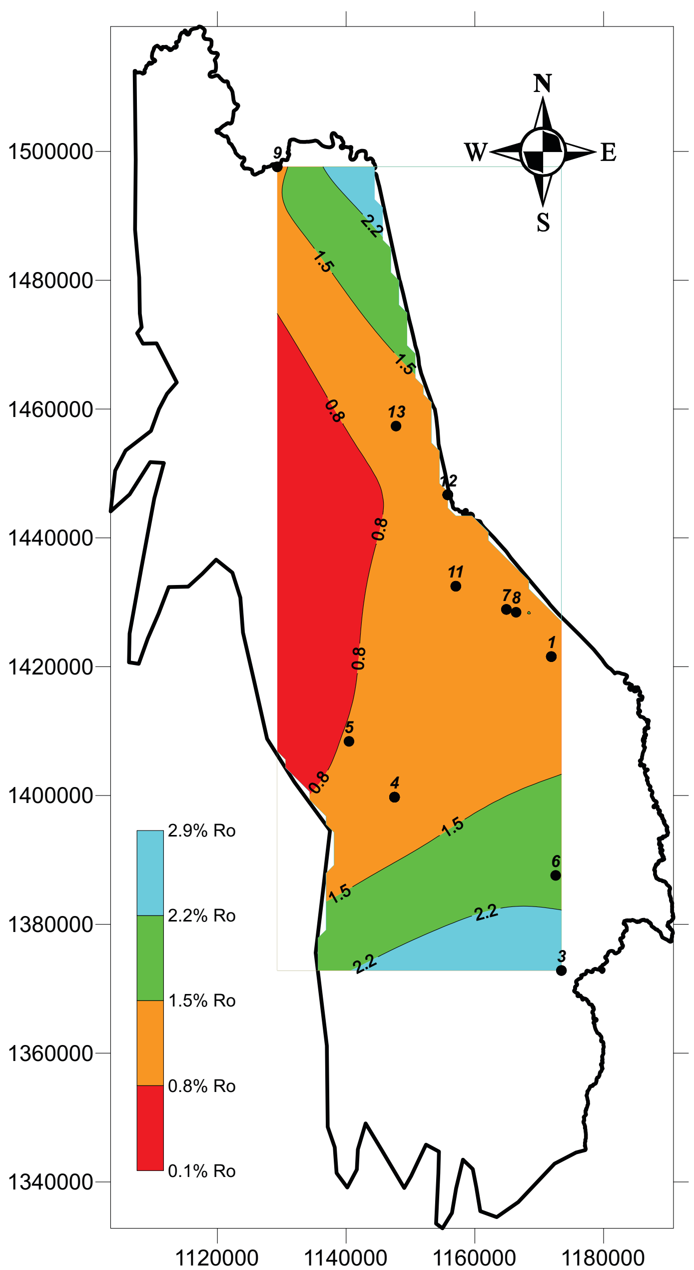
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from Cretaceous units (Uribante Group, La Luna, Capacho and Catatumbo formations) and Cenozoic units (Barco, Los Cuervos and Carbonera formations), with good to excellent oil generation potential (S2 up to 35 mg HC/g rock and % TOC up to 9). In the case of the Upper Cretaceous Mito-Juan Formation and the Cenozoic Guayabo and León formations their samples indicate poor oil generation potential (S2 < 5 mg HC/g rock and %TOC < 1) (Figure A). Generation potential is reduced by high thermal maturity, especially in units like La Luna and Capacho formations and the Uribante Group.

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence deposited in the basin is mostly mature to overmature which is in good agreement with the API Gravity and high thermal maturity of the oils found (Figure B).

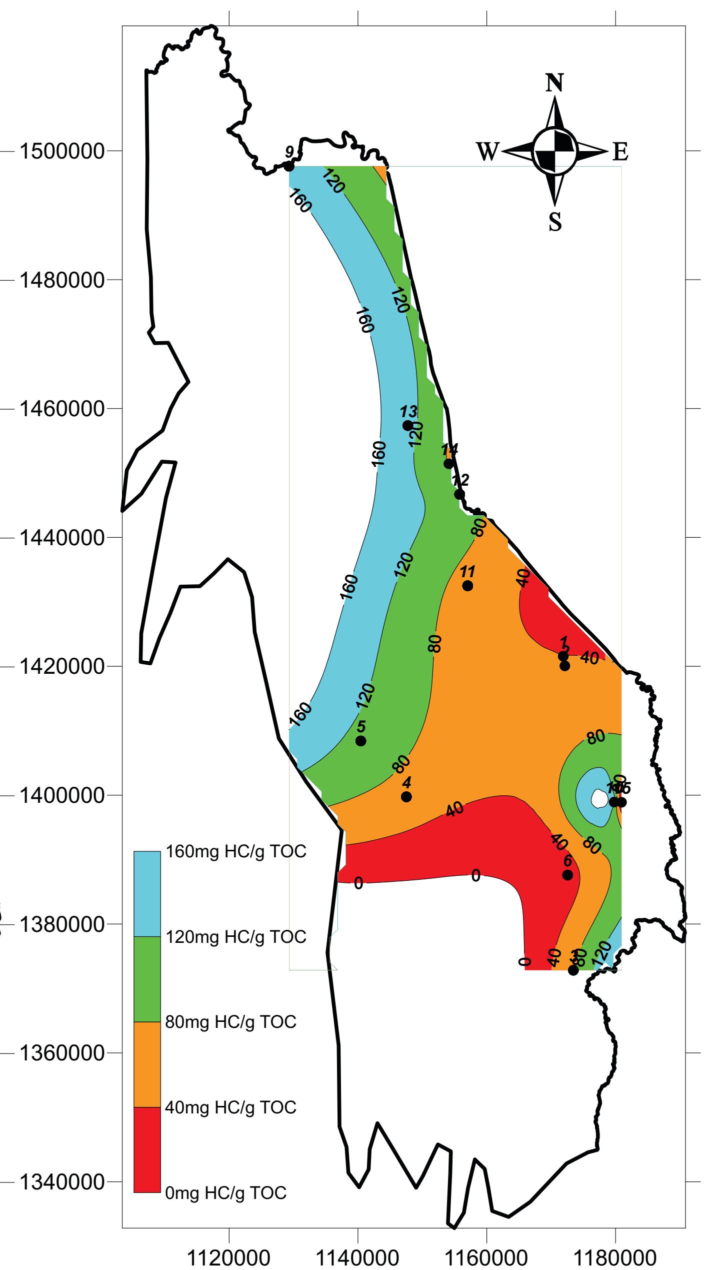
-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Cretaceous rocks of the Uribante Group, and La Luna, Capacho and Catatumbo formations. The Cenozoic rocks of the Barco and Carbonera formations also have good to excellent generation potentials. Thermal maturity data (Tmax and %Ro) indicates that the Cretaceous oil-prone formations are the more mature sources for the hydrocarbons in the basin, and that the Cenozoic Barco and Carbonera formations are also in an earlier maturity stage in the basin.

Source Rock Quality and Maturity Maps

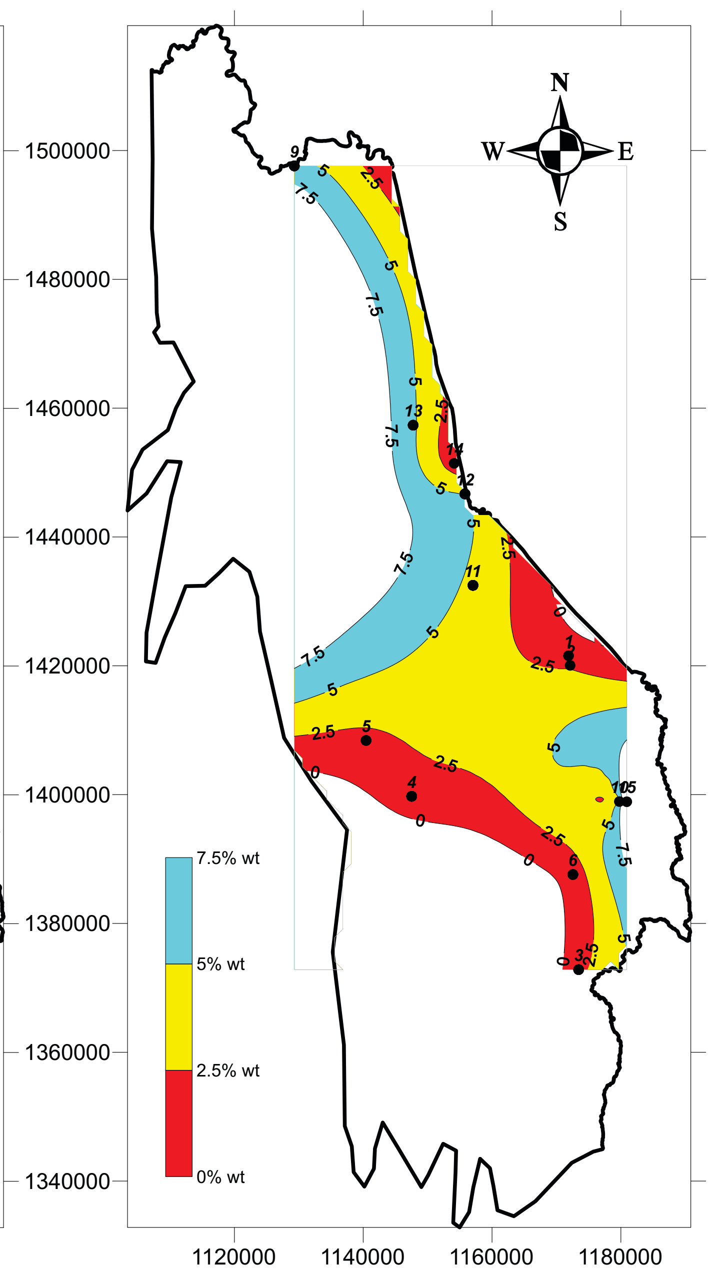
La Luna Formation



Vitrinite Reflectance (%Ro)



Hydrogen Index



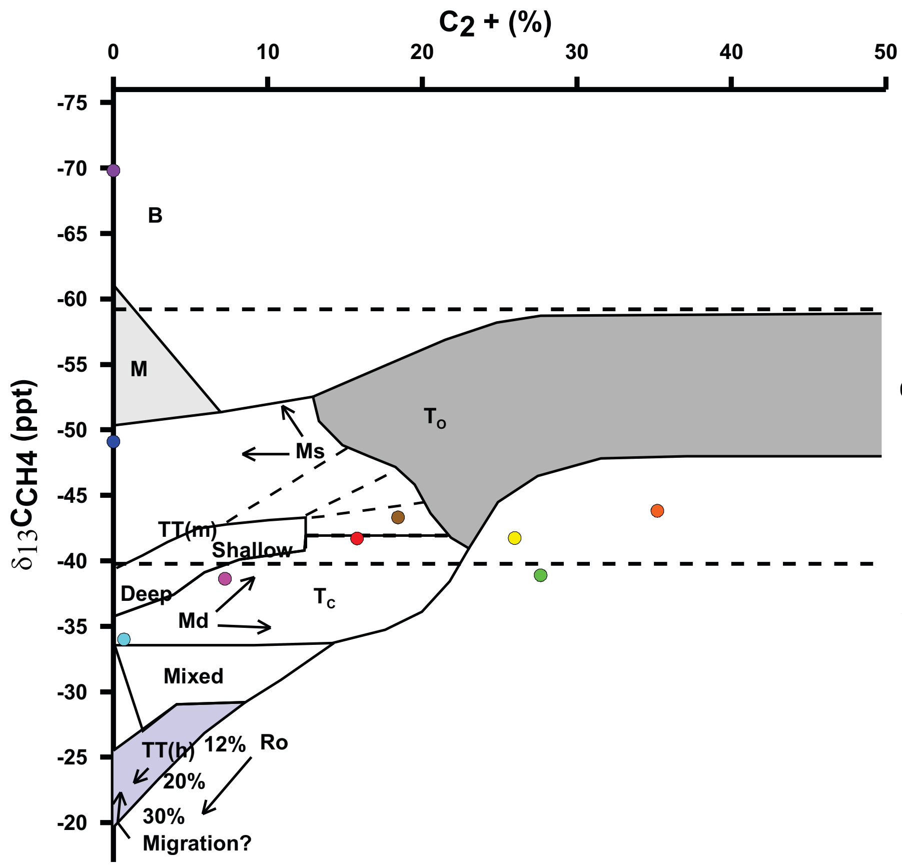
Organic Matter Content (TOC)

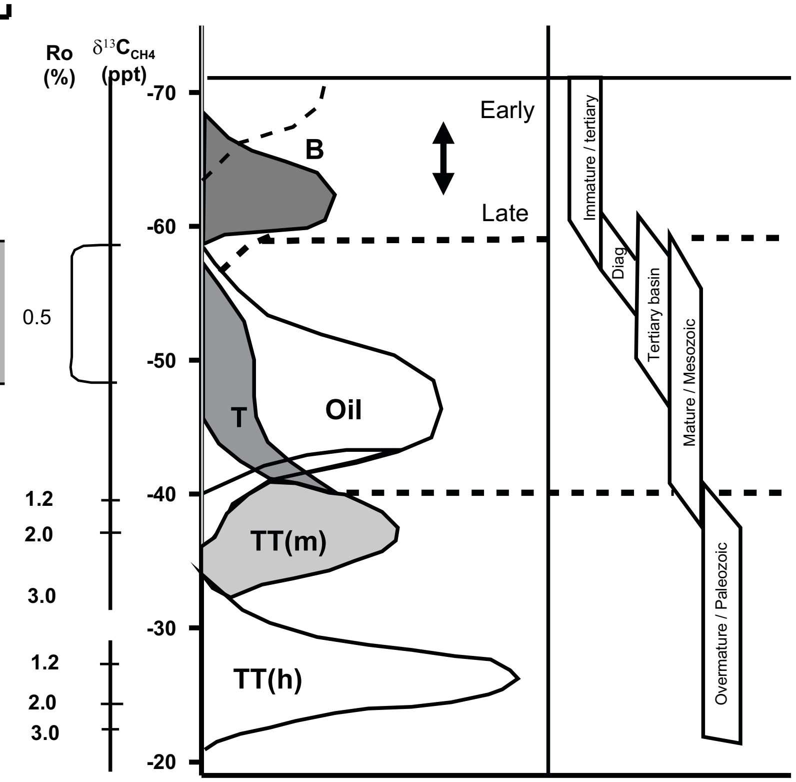
LEGEND

1. CARBONERA-4K
2. CARBONERA-5K
3. CERRITO-1
4. CERRO GORDO-3
5. ESPERANZA-3
6. MUCURERA-3
7. PETROLEA-108
8. PETROLEA-91
9. RÍO DE ORO-14
10. RÍO ZULIA-14
11. SARDINATA-3K
12. TIBU-178K
13. TIBÚ-2K
14. TIBÚ-91K
15. ZULIA EAST-1

Map datum: Magna Sirgas
Coord. origin: Bogotá

Gas Characterization

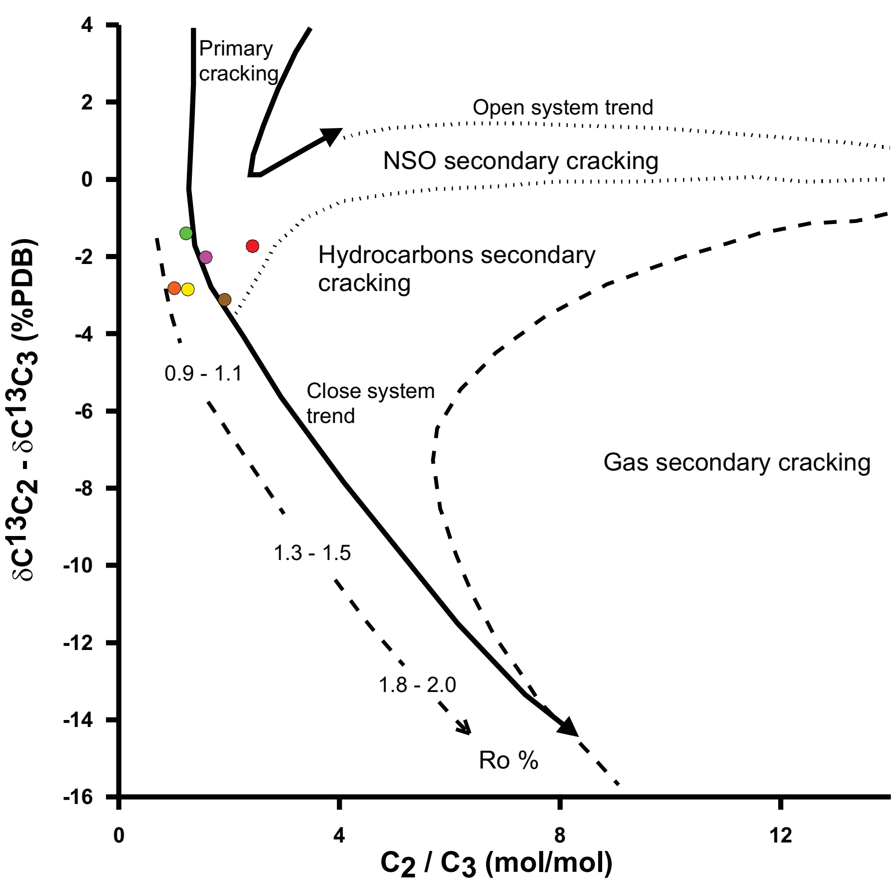




B	Biogenic gas
T	Crude oil gases
To/Tc	Crude and condensate gases
TT(m)	Dry gases associated to sapropelic organic matter.
TT(h)	Gases associated to humic organic matter
M	Mixed gases
Md	Deep Migration
Ms	Shallow Migration

LEGEND

- CARBONERA Caña Brava
- CERRITO-1
- PETROLEA-29
- RIO ZULIA-29
- SARDINATA N3K
- SARDINATA S32K
- TIBU -4K
- TIBU 191K
- TORTEROS



- The samples analized in the Catatumbo Basin include gases associated to samples from coal mines (Torteros and Caña Brava - Carbonera).

- The C2+(%) vs d13C Ch4 (ppt) diagram (Schoell, 1983), suggests that the well samples correspond to thermogenic gases, sourced from organic matter at different maturity levels. These gases indicate deep to shallow migration. On the other hand the gas samples taken from the El Tortero and Caña Brava - Carbonera mines, correspond to humic organic matter sources.

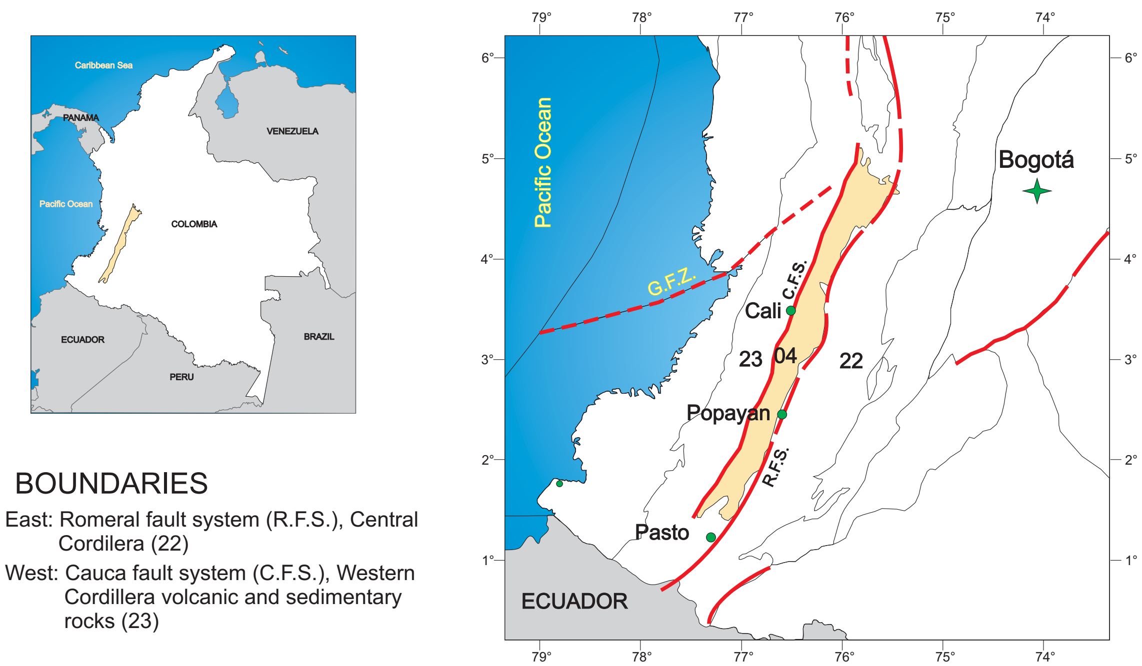
- The C2/C3 vs d13C C3 diagram, suggests that the gas samples analized were originated by primary cracking.

CAUCA- PATÍA BASIN

Generalities
Wells and Seeps
Depositional Environments
Source Rock Characterization
Surface Geochemistry

Generalities

CAUCA - PATÍA BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

East: Romeral fault system (R.F.S.), Central Cordilera (22)

West: Cauca fault system (C.F.S.), Western Cordillera volcanic and sedimentary rocks (23)

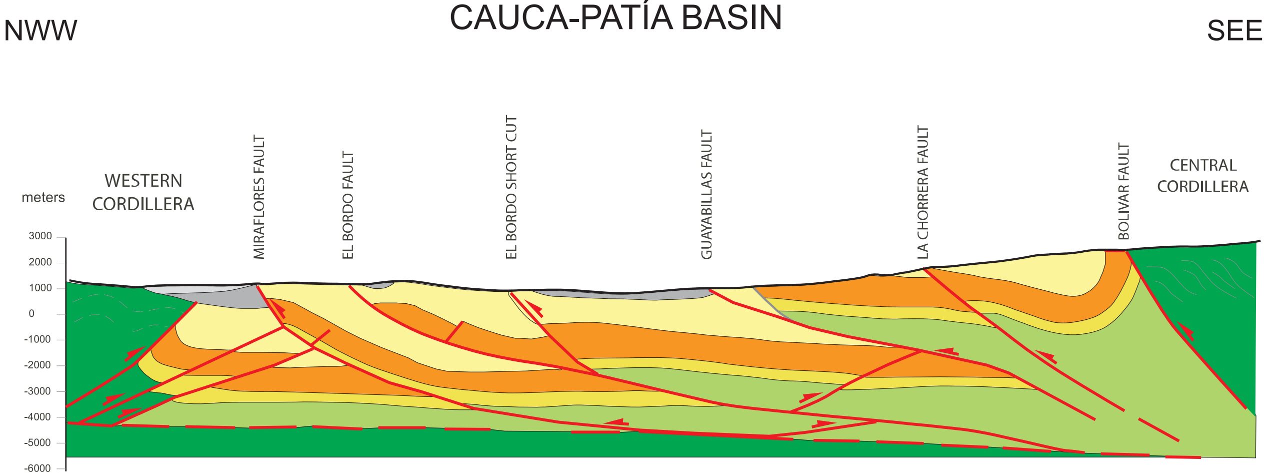
G.F.Z. Garrapatas fault system

From Barrero et al., 2007

The source rock geochemical information interpreted for the Cauca Patía Basin includes %TOC and Rock-Eval Pyrolysis data from 326 samples; additionally 96 organic petrography samples were interpreted.

Crude oil information from 54 liquid chromatography samples, 395 gas chromatography samples, 24 biomarker samples, 66 isotopes and 1239 surface geochemistry samples were also interpreted.

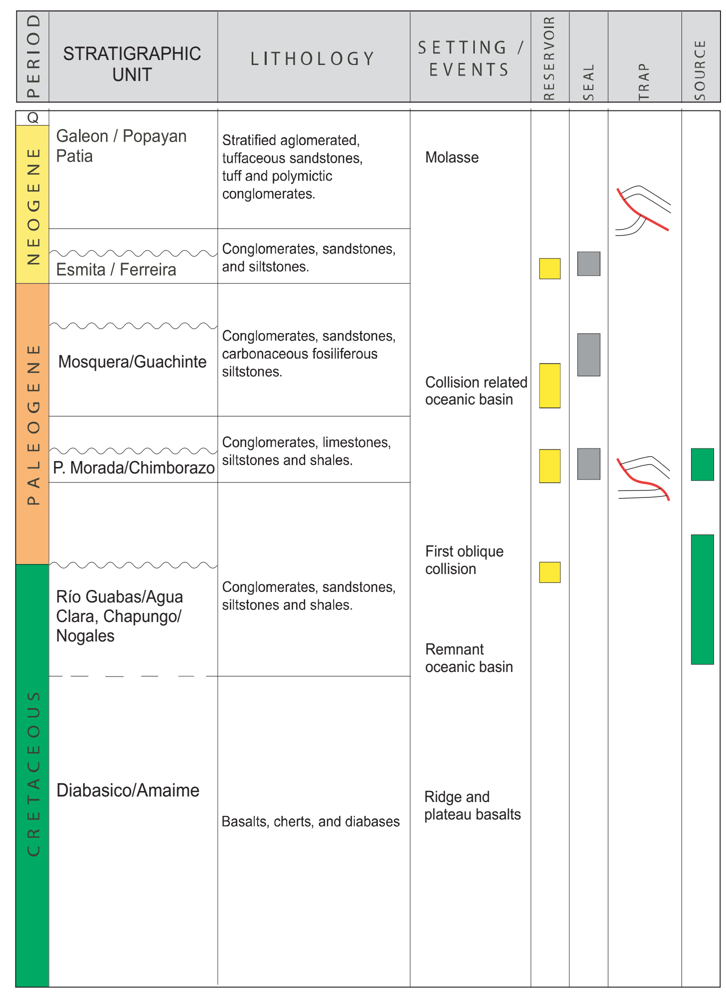
CROSS SECTION
CAUCA-PATÍA BASIN



Taken from Barrero-Lozano D., et al. 2006

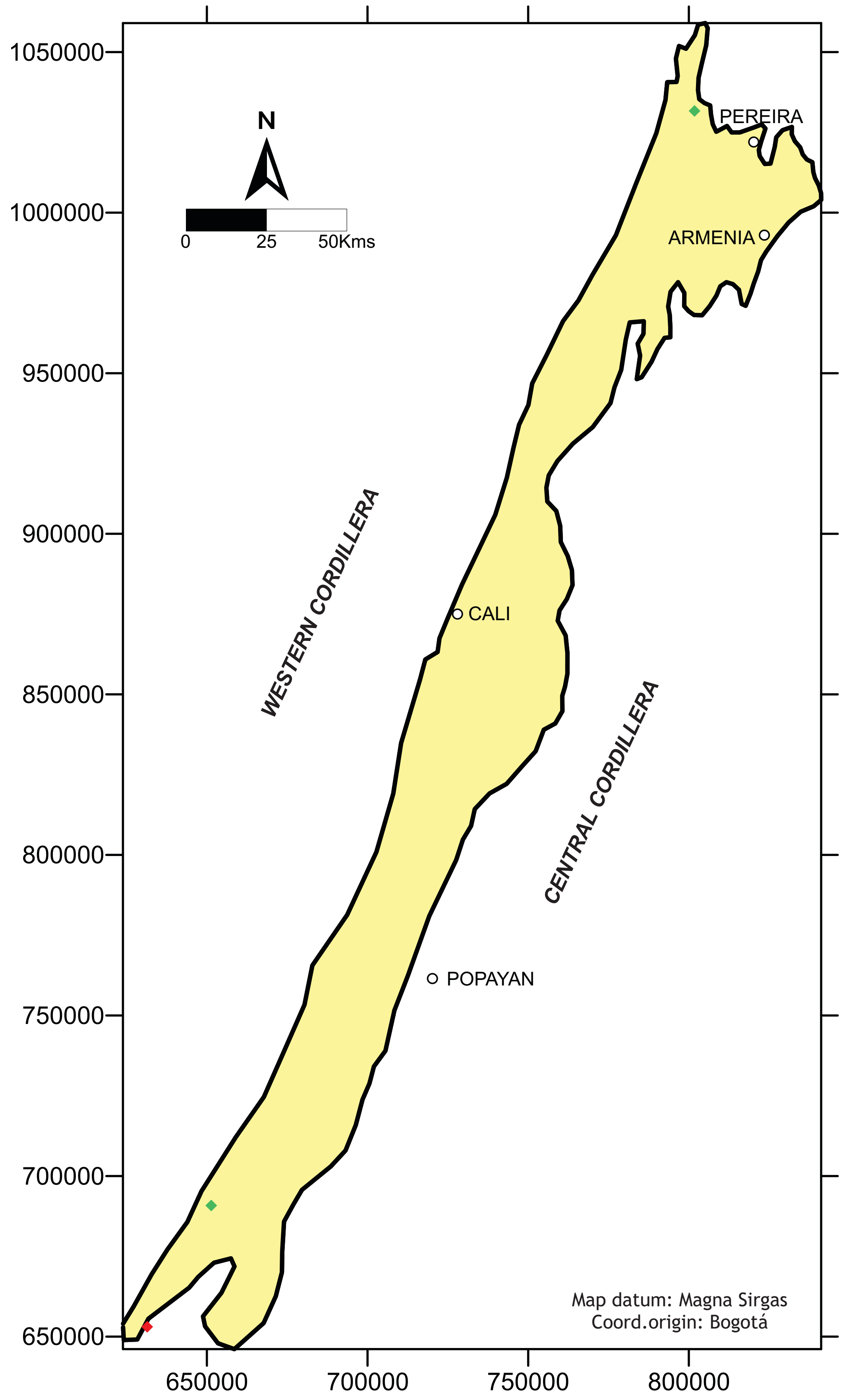
Cretaceous Paleogene Neogene

From Barrero et al., 2007

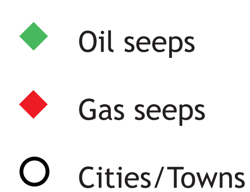


From Barrero et al., 2007

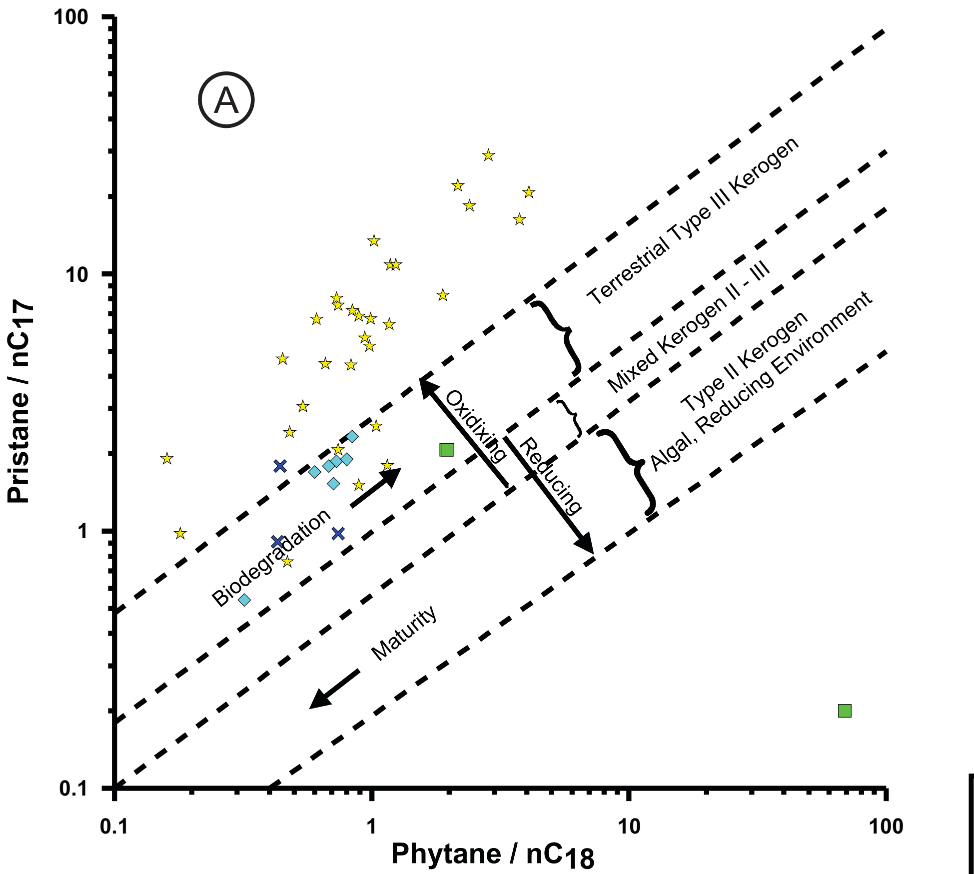
Wells and Seeps

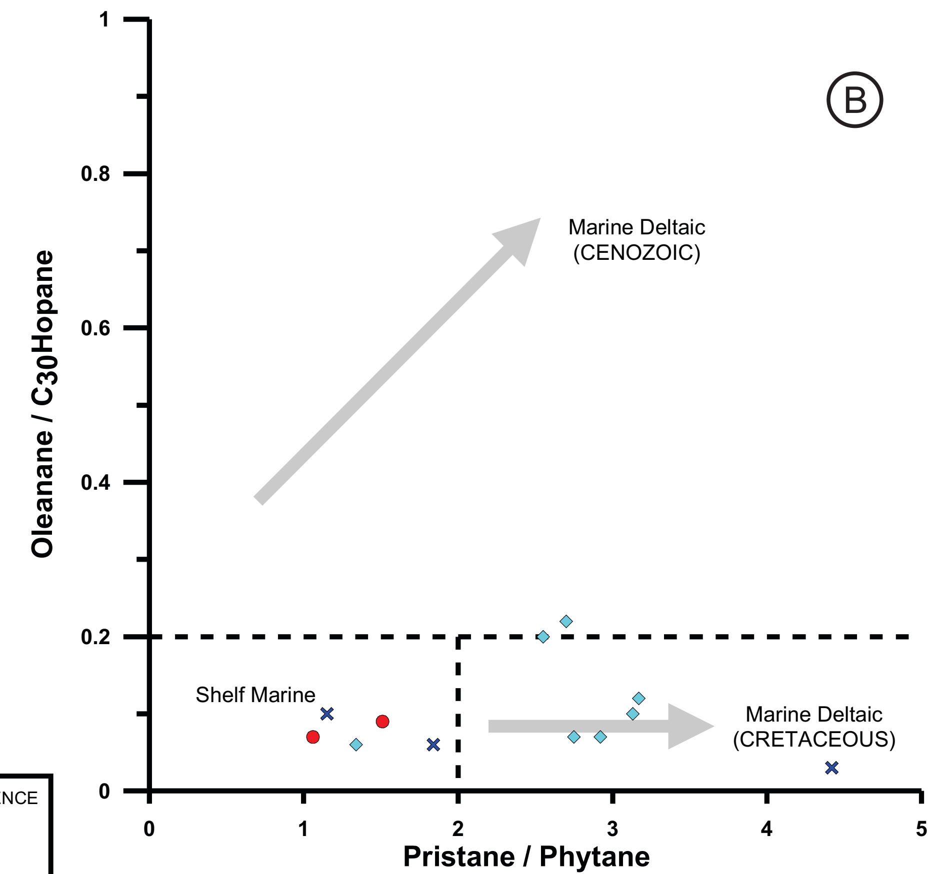


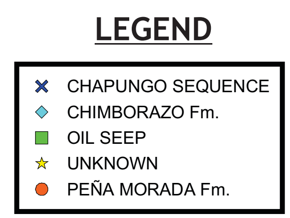
Two seeps are reported at the southern part of the basin and one in its northern part.

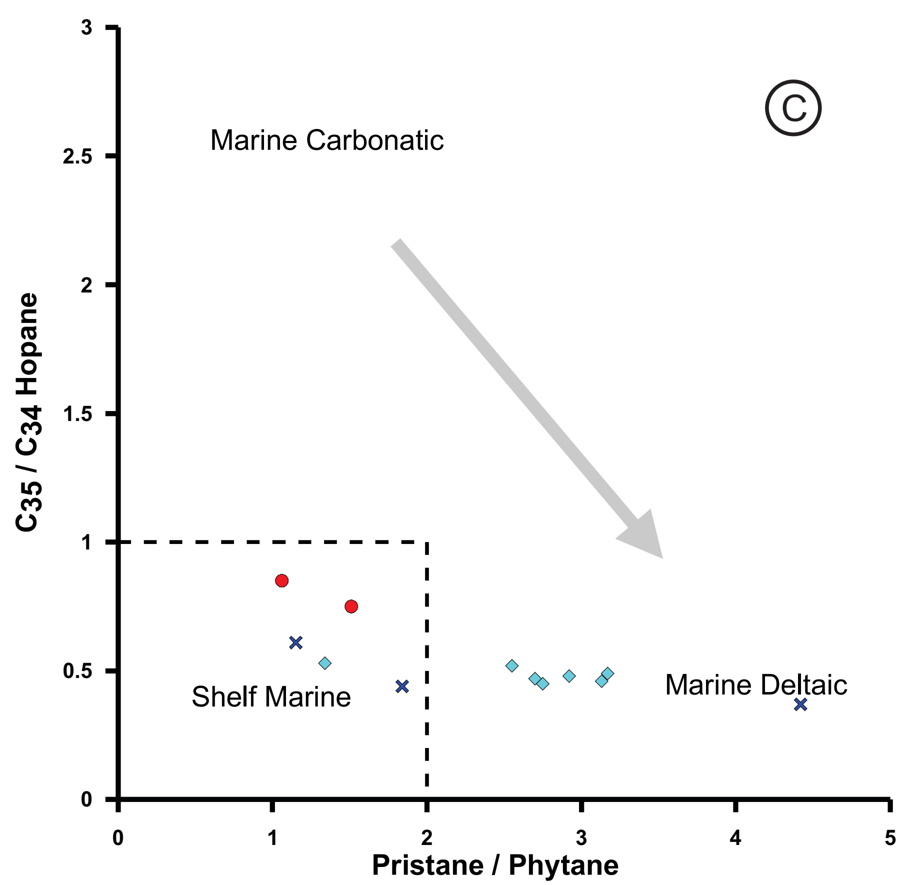


Depositional Environments







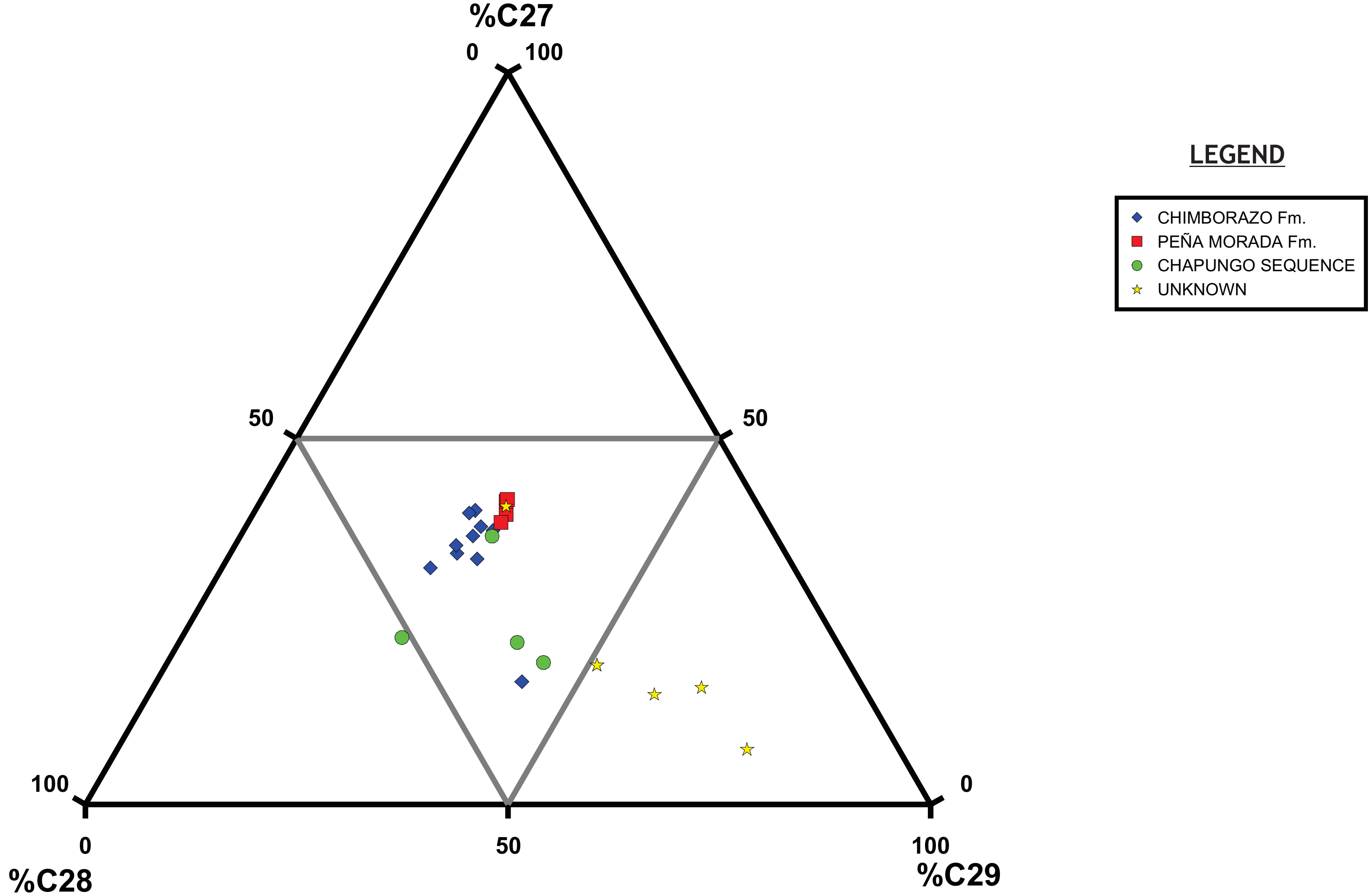


- The Phytane/nC18 vs Pristane/nC17 graph that the rock extracts from outcrop samples and two seep samples in the basin have origin from terrestrial organic matter (Type III kerogen) deposited in an oxidizing environment. Another oil seep sample with very high Phytane/nC18 value suggests generation from marine organic matter (Type II kerogen) in very reducing conditions (Figure A).

- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that half of the rock extracts have low oleanane index values (<0.2) and Pr/Ph values (<2) which indicates that these oils are generated from source rocks deposited in shelf marine environments, and the other half have low oleanane index values but high Pr/Ph (>2) indicating that these extracts were generated from source rocks deposited in marine deltaic environments. The oleanane index has been also used as an age indicator of the source rock, with high oleanane values for oils generated in Cenozoic rocks and low oleanane values in oils from older rocks (Figure B).

- The Pristane/Phytane vs C35/C34 Hopane (Homohopane index) graph shows that all the rock extracts have C35/C34 Hopane values below 1 and variable Pr/Ph (from 1 to 5), indicating that these extracts were generated from siliciclastic rocks deposited in shelf marine and marine deltaic environments. (Figure C).

Depositional Environments

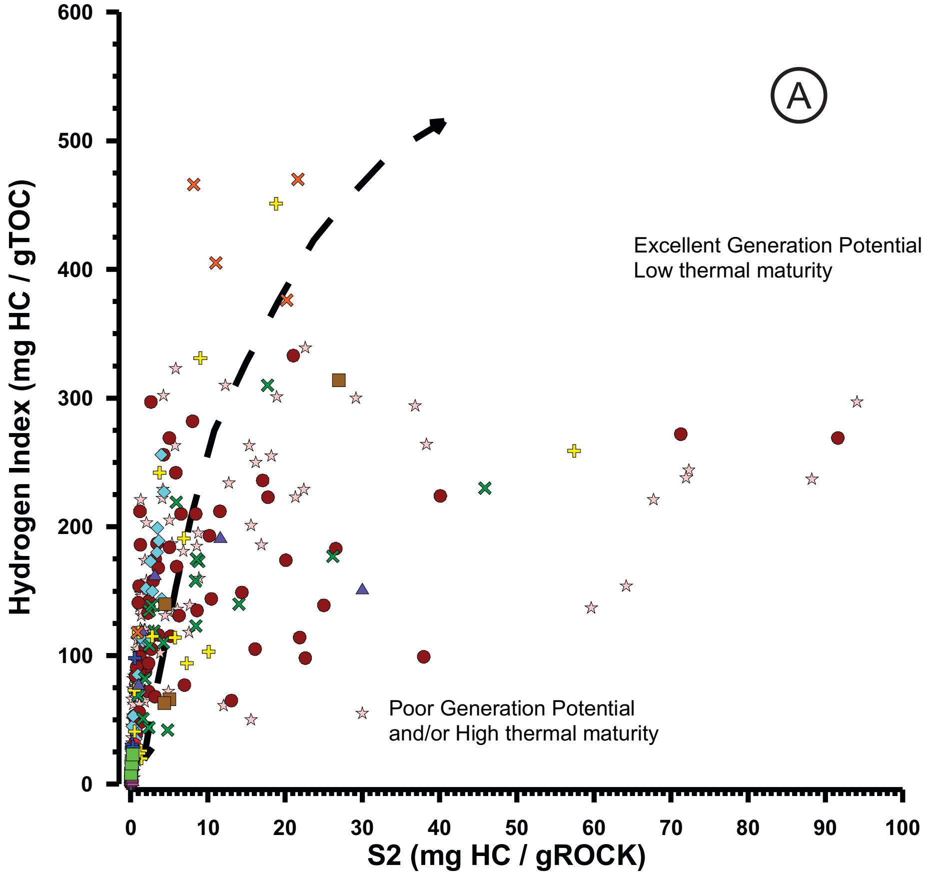


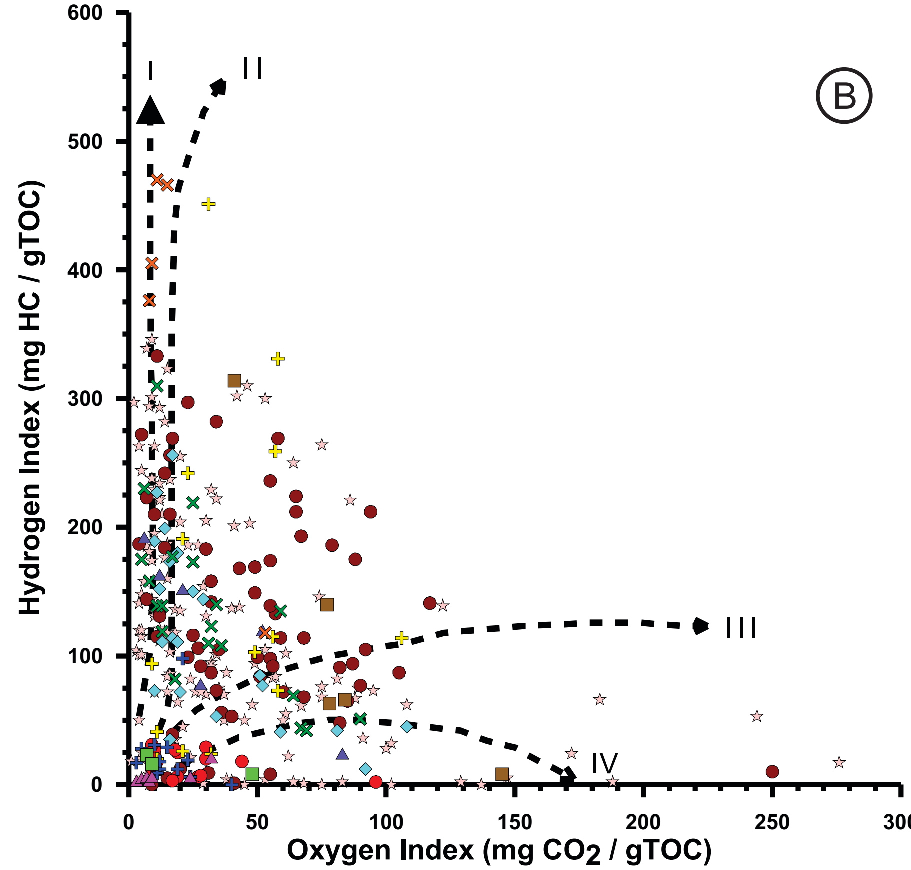
- The steranes ternary diagram (%C27, %C28 and %C29) shows that the rock extracts from the Chimborazo and Peña Morada formations have a higher proportion of C27 steranes, indicative of more marine organic matter input, and extracts from the Chapungo sequence have a higher proportion of C29 steranes indicative of more terrestrial organic matter input.

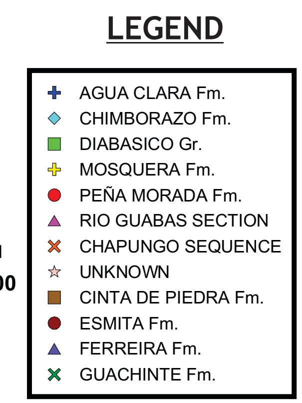
- In summary, rock extracts from the Paleocene Chimborazo Formation are characterized by showing Pristane/Phytane > 2.0, C35/C34 hopanes < 1.0, and Oleanane/C30 Hopane < 0.2 and predominance of C27/C29. Indicative of rocks deposited under marine deltaic conditions with terrigenous input.

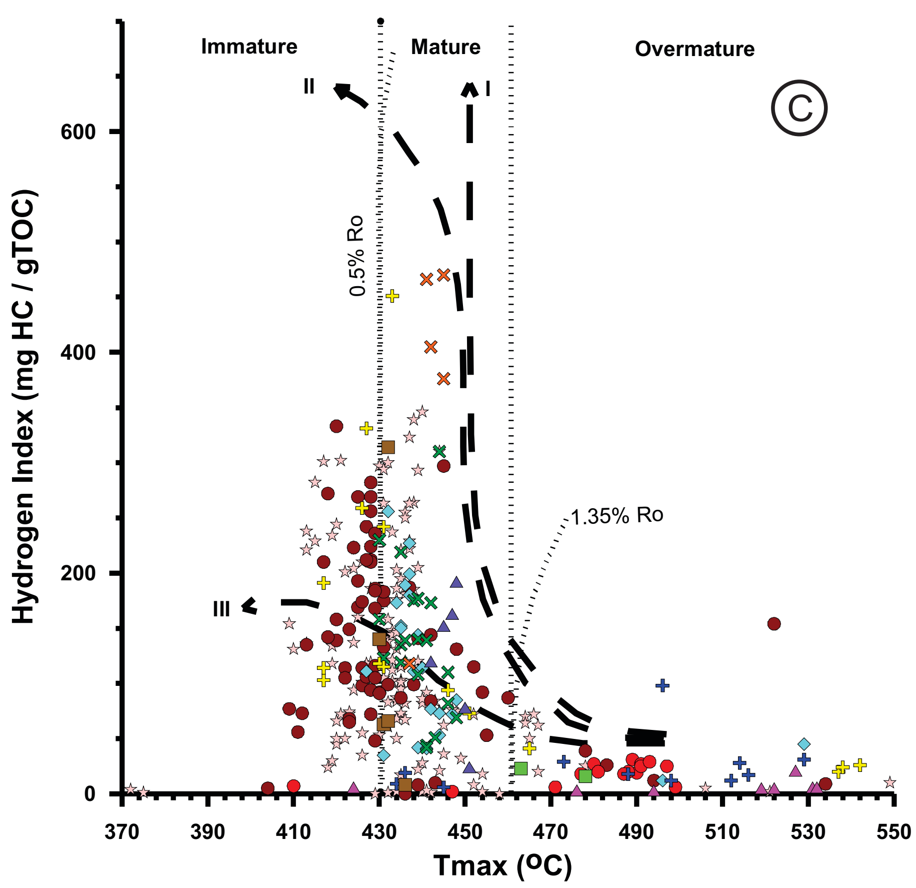
- Rock extracts from the Paleocene Peña Morada formation and Cretaceous Chapungo sequence are characterized by showing Pristane/Phytane < 2.0, C35/C34 hopanes < 1.0, and Oleanane/C30 Hopane < 0.2. Indicative of rocks deposited under marine conditions with low terrigenous input.

Source Rock Characterization







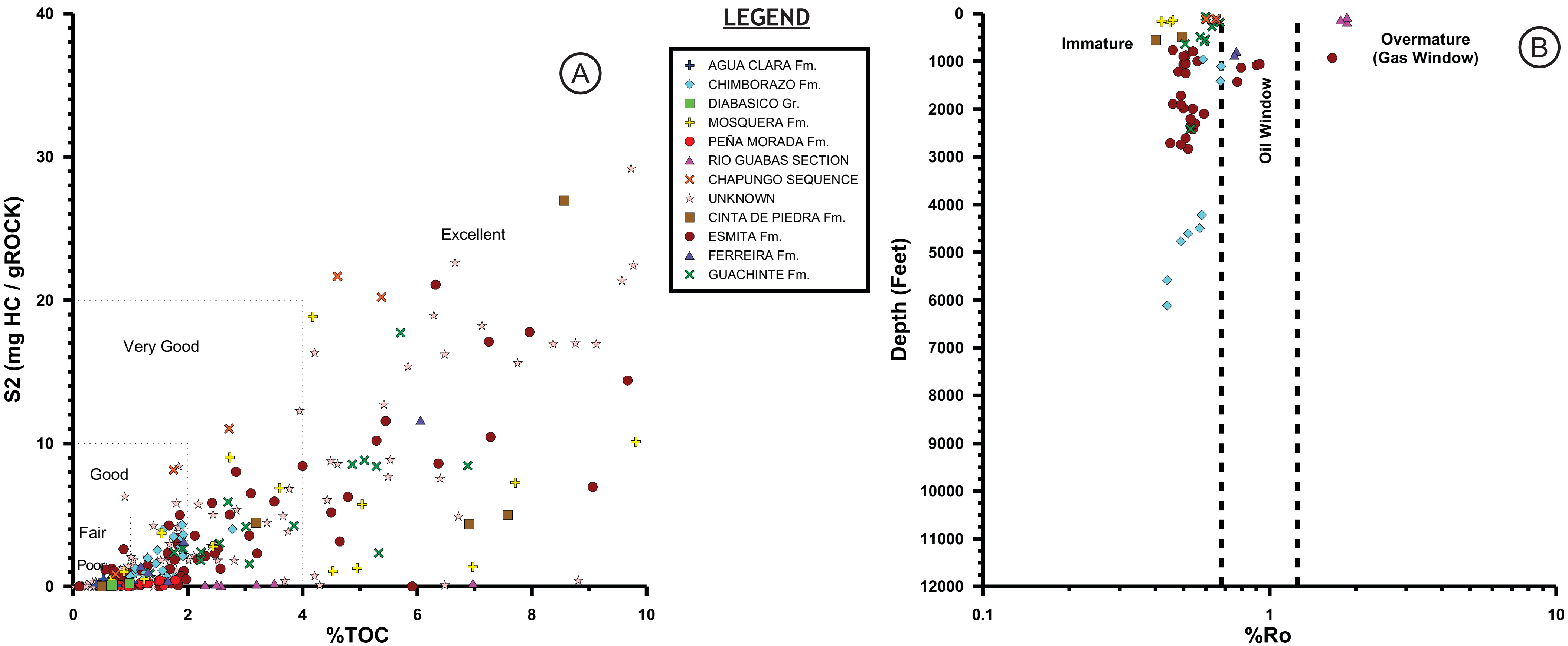


- The data obtained from pyrolysis of outcrop samples for Hydrogen Index (HI) and S2 peak, indicate that most of the samples collected in the basin have poor generation potential (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock) however samples with good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock) were obtained from the Cretaceous Chapungo Sequence, and from the Cenozoic Chimborazo, Guachinte, Mosquera and Esmita formations (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cretaceous Chapungo Sequence and Cenozoic Chimborazo, Guachinte, Mosquera and Esmita formations have type II oil-prone kerogen. There are also samples from these formations with type III gas-prone characteristics along with samples of the Cenozoic Cinta de Piedra, Peña Morada and Ferreira formations (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples from the Cretaceous to Cenozoic units mentioned are mature to overmature in the basin (Figure C). There is no clear correlation between stratigraphic position and thermal maturity, because younger and older rocks have similar maturities, which suggests that there is some process in the basin affecting in the same way the whole stratigraphic sequence, possibly related to the extensive presence of intrusive rocks in the basin.

Source Rock Characterization

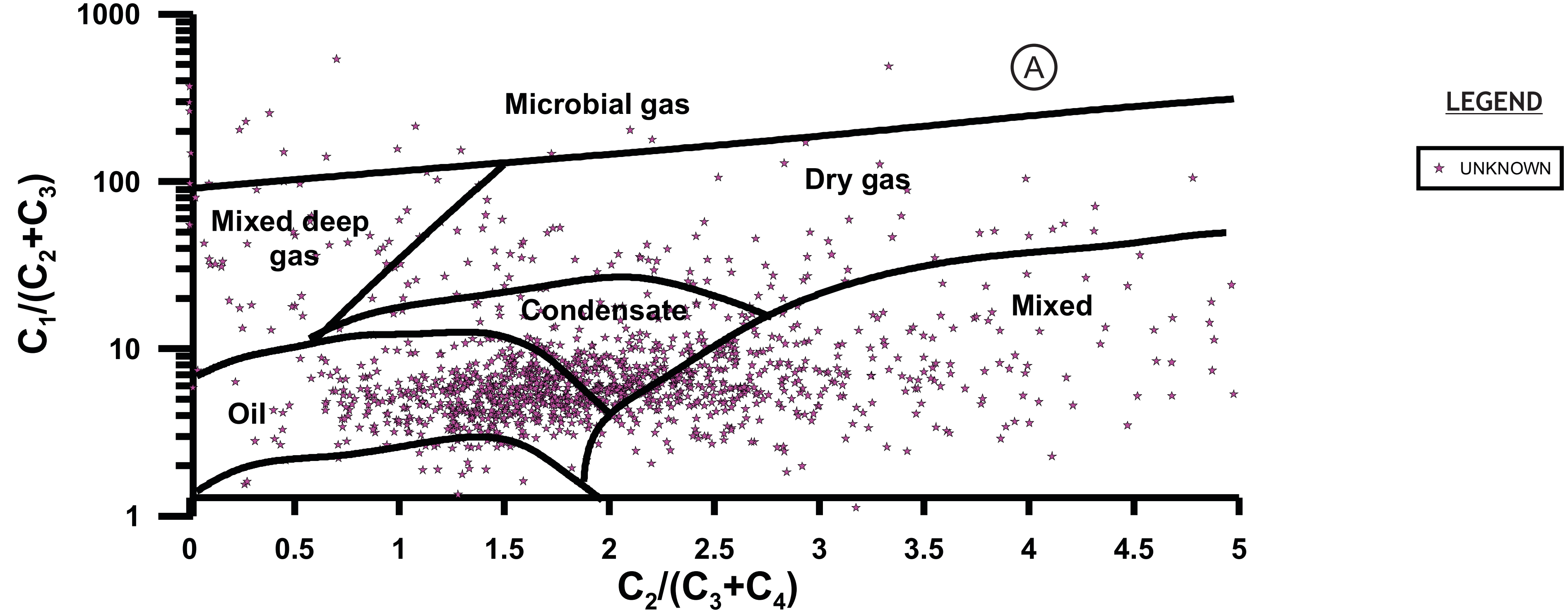


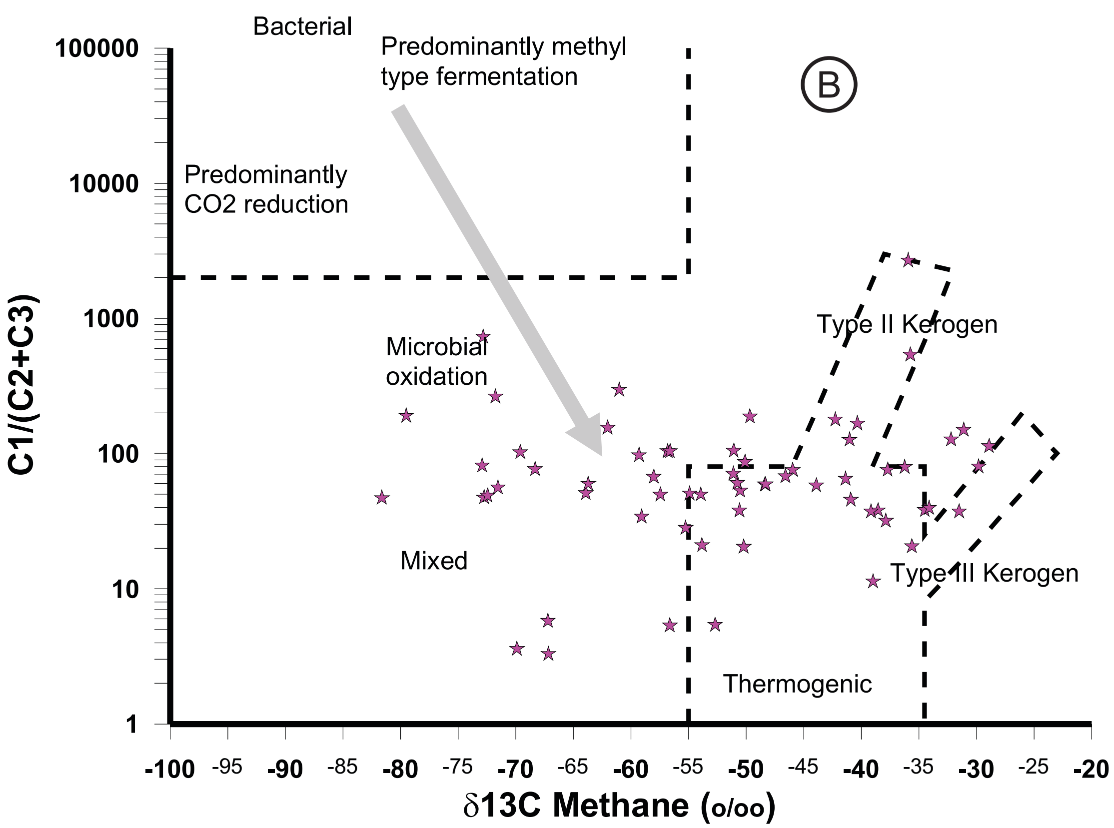
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from Cretaceous (Chapungo sequence) and Cenozoic units (Mosquera, Ferreira, and Esmita formations) with good to excellent oil generation potential (S2 up to 50 mg HC/g rock and % TOC up to 9). Additionally this graph shows that samples from the Cretaceous Río Guabas Formation and Cenozoic Mosquera and Cinta de Piedra formations, although have good to excellent TOC values (up to 10 wt%), do not have good S2 values (< 5 mg HC/g rock), indicating that the kerogen in these formations is not labile and appropriate for liquid hydrocarbons generation (Figure A).

-The vitrinite reflectance (%Ro) information shows that most of the samples are immature or close to early maturity in the basin. However some samples are in the oil generation window and even overmature in accordance with Tmax data. In this graph it is important to notice that due to the fact that the samples were taken from outcrops, the depth is a relative depth corresponding to the stratigraphic position of the samples in the field column and not burial depths (Figure B).

-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Cretaceous rocks of the Chapungo Sequence and the Cenozoic rocks of the Mosquera, Ferreira and Esmita formations. Maturity data from outcrop samples indicate that the oil-prone formations are mature for hydrocarbons generation, and that good quality oils could be expected from the high thermal maturity reached by some potential source rocks in the basin.

Surface Geochemistry





Compositional data from surface geochemistry samples indicate that most of the hydrocarbons in the basin are thermogenic, formed mainly during oil generation window with minor presence of high maturity hydrocarbons (gas generation window). There are very few samples of microbial gas to consider biogenic gas an important process in the basin. (Figure A).

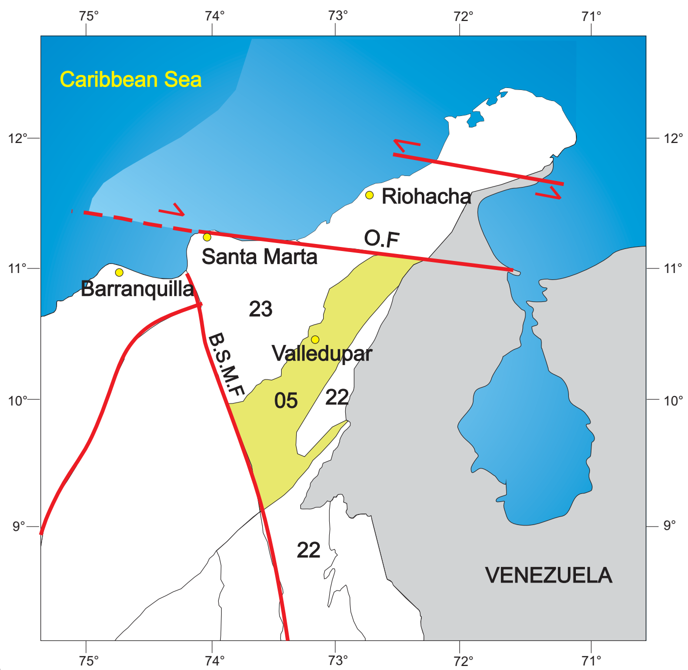
Isotopic data from these type of samples indicate thermogenic origin of the gases with mixing between different thermal maturity hydrocarbons, generation from type II and III kerogens, and to a minor extent microbial oxidation (Figure B).

CESAR RANCHERIA BASIN

Generalities
Wells and Seeps
Source Rock Characterization
Source Rock Quality and Maturity Maps
Surface Geochemistry

Generalities

CESAR RANCHERÍA BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

NE: Oca Fault (O.F.)

E-SE: Pre-Cretaceous rocks of the Serranía de Perijá (22); Colombian-Venezuelan boundary.

SW: Bucaramanga-Santa Marta Fault (B.S.M.F)

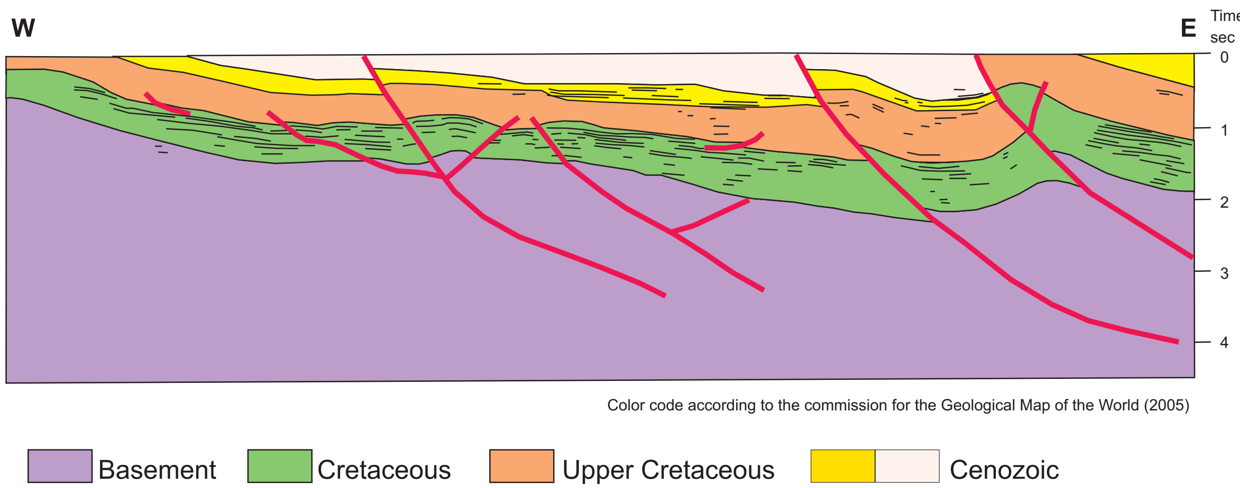
NW: Pre-Cretaceous rocks of the Sierra Nevada de Santa Marta (23)

From Barrero et al., 2007

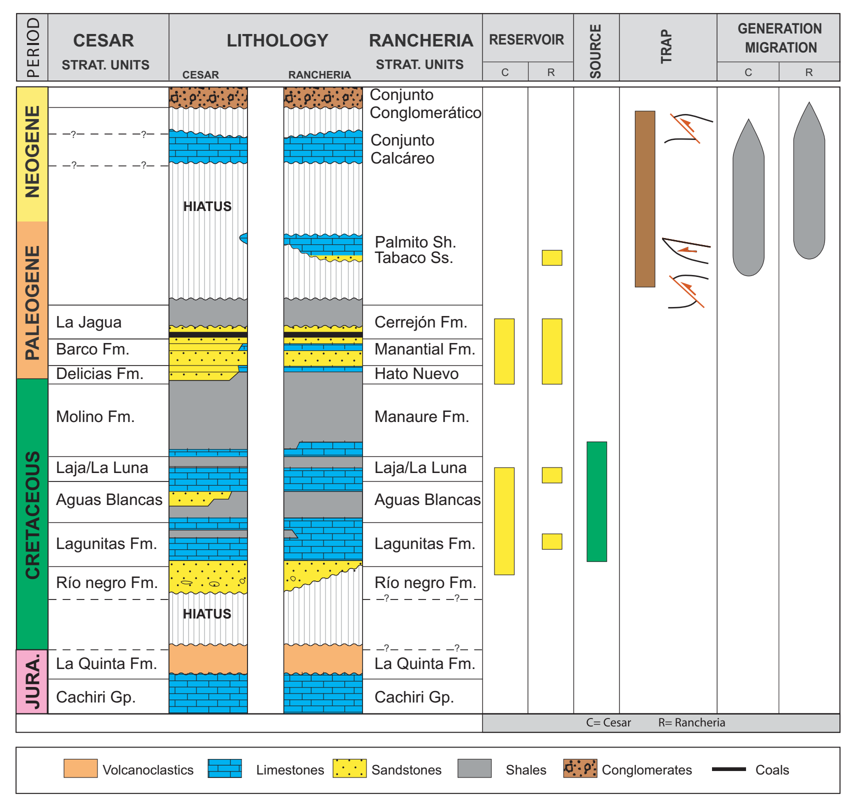
The source rock geochemical information interpreted for the Cesar - Ranchería Basin includes %TOC and Rock-Eval Pyrolysis data from 417 samples taken in 4 wells and 81 samples from outcrops; additionally 91 organic petrography samples from 4 wells and 62 samples from outcrops, and 417 surface geochemistry samples were also interpreted.

Due to the lack of crude oil geochemical data, crude oil interpretation can not be made for the basin.

SCHEMATIC CROSS SECTION
CESAR - RANCHERIA BASIN

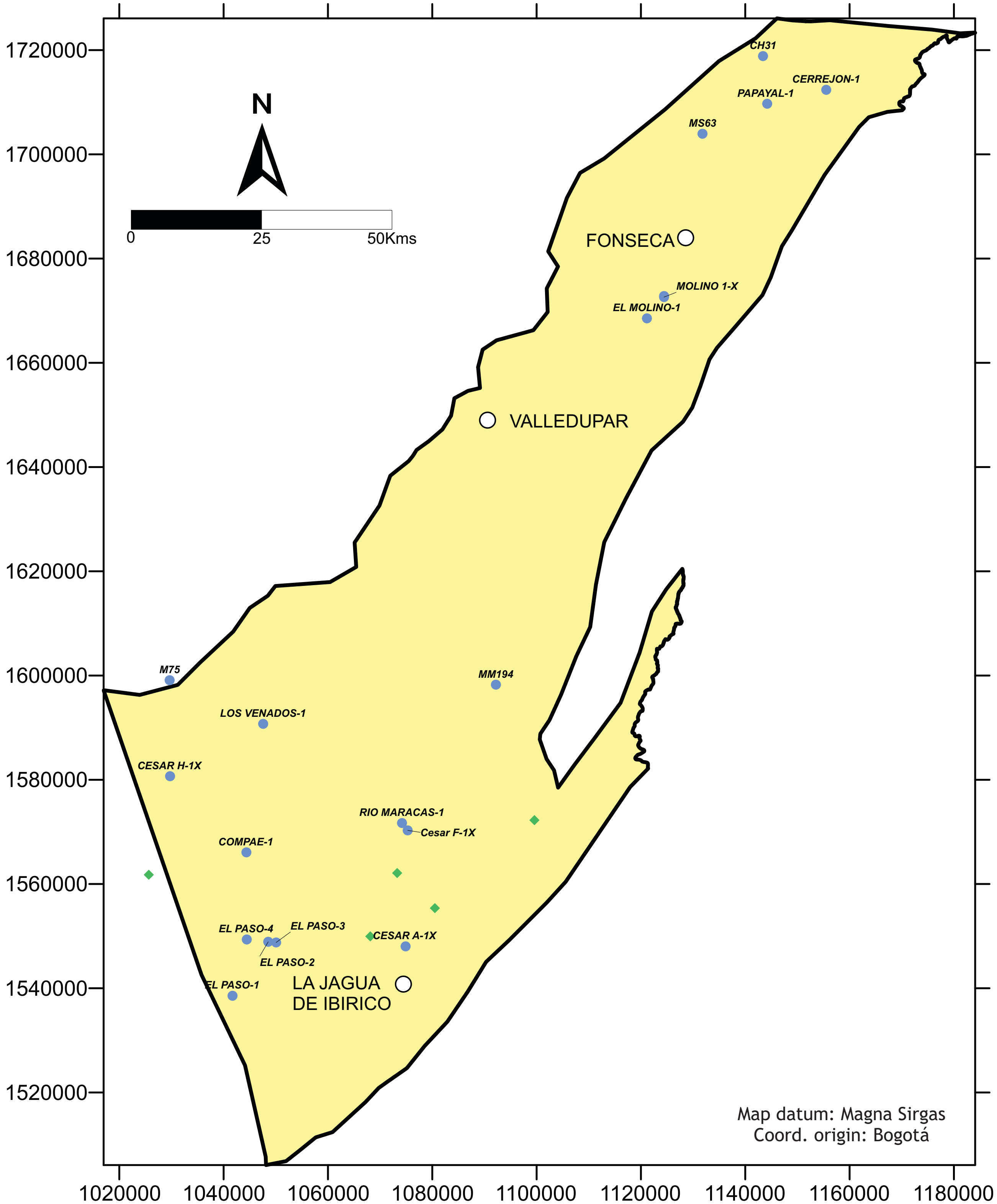


From Barrero et al., 2007



From Barrero et al., 2007

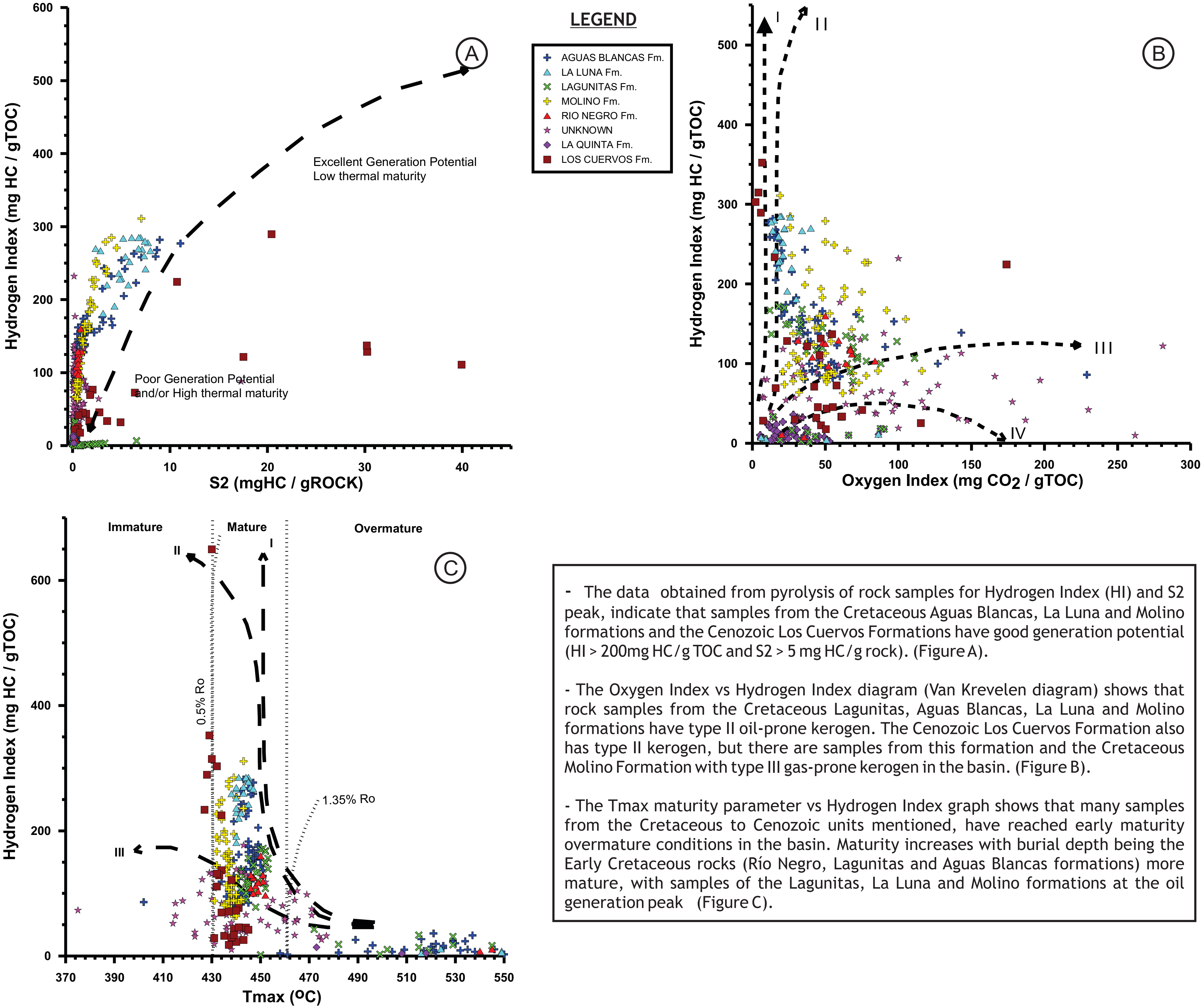
Wells and Seeps



The number of wells and/or surface locations with geochemical information in the Cesar - Ranchería Basin is 18.

- Wells with geochemical information
- Oil seeps
- Cities/Towns

Source Rock Characterization

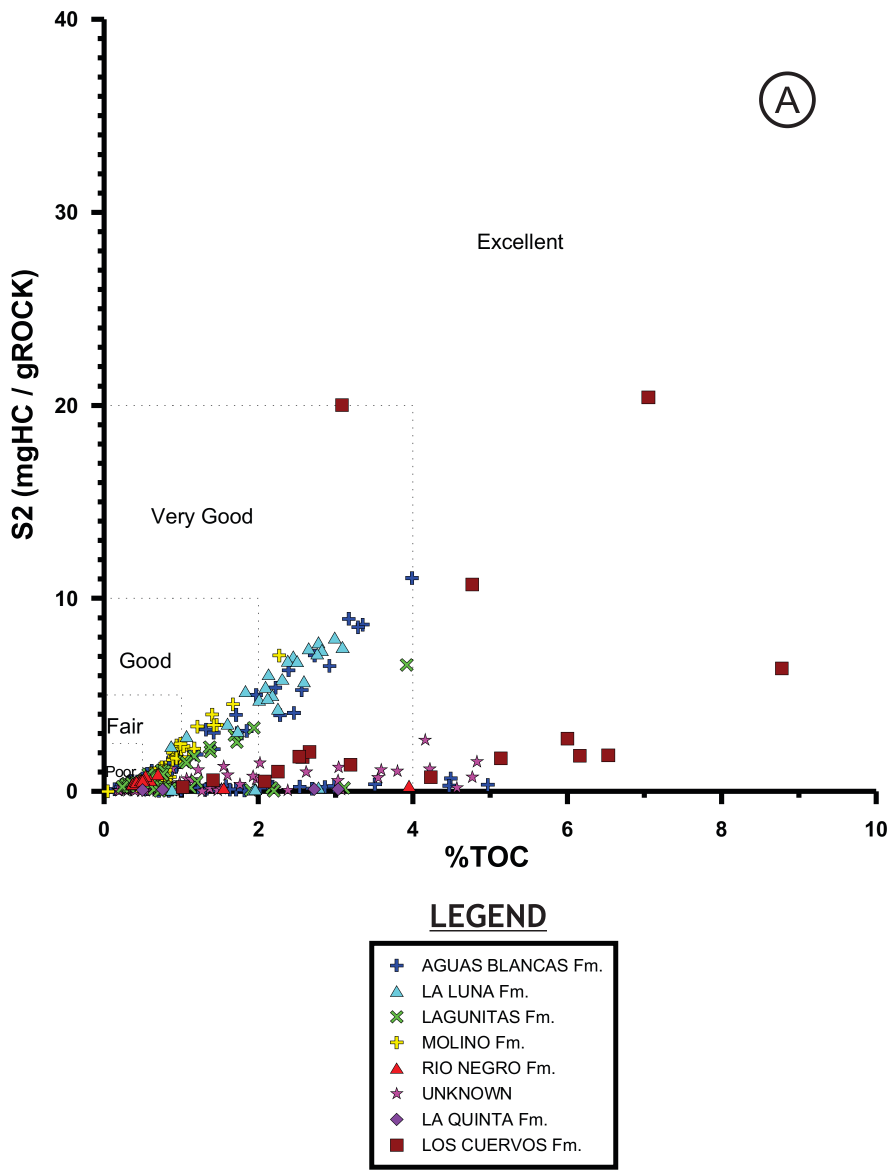


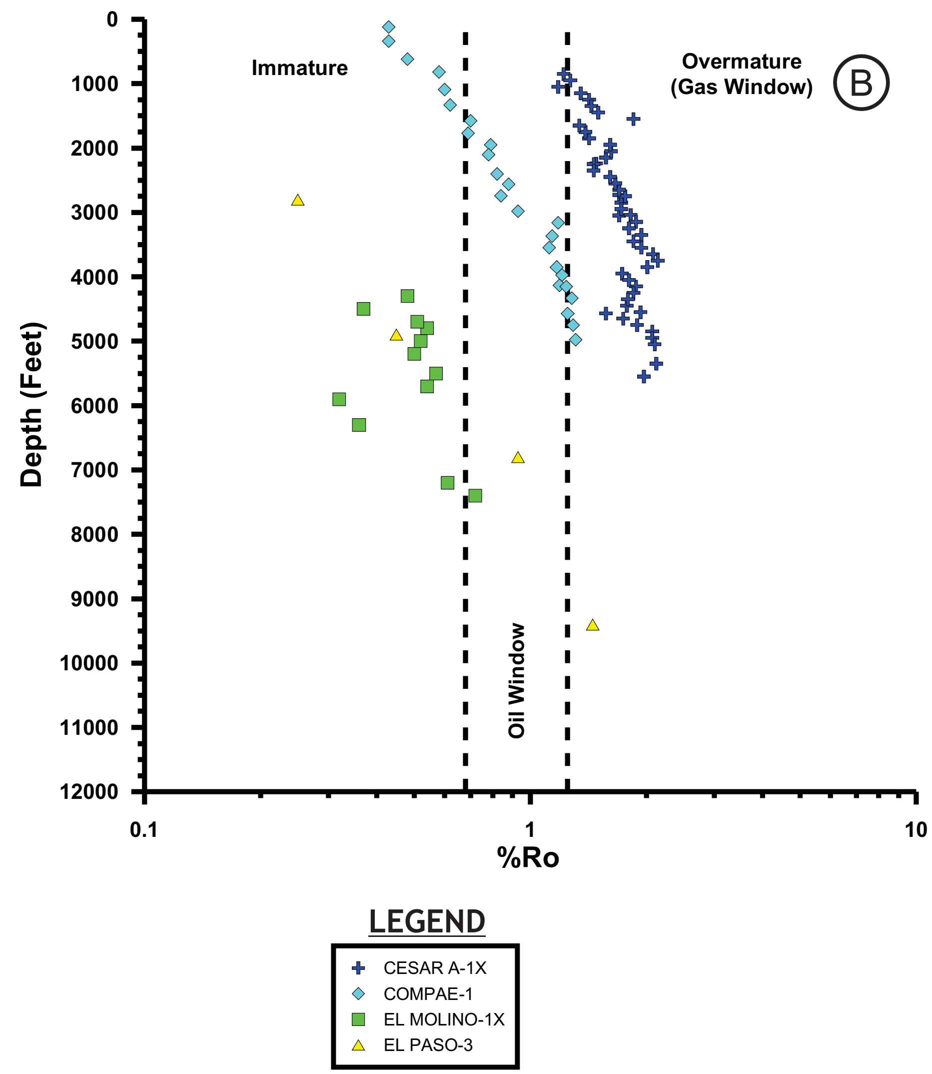
- The data obtained from pyrolysis of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Cretaceous Aguas Blancas, La Luna and Molino formations and the Cenozoic Los Cuervos Formations have good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock). (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cretaceous Lagunitas, Aguas Blancas, La Luna and Molino formations have type II oil-prone kerogen. The Cenozoic Los Cuervos Formation also has type II kerogen, but there are samples from this formation and the Cretaceous Molino Formation with type III gas-prone kerogen in the basin. (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples from the Cretaceous to Cenozoic units mentioned, have reached early maturity overmature conditions in the basin. Maturity increases with burial depth being the Early Cretaceous rocks (Río Negro, Lagunitas and Aguas Blancas formations) more mature, with samples of the Lagunitas, La Luna and Molino formations at the oil generation peak (Figure C).

Source Rock Characterization





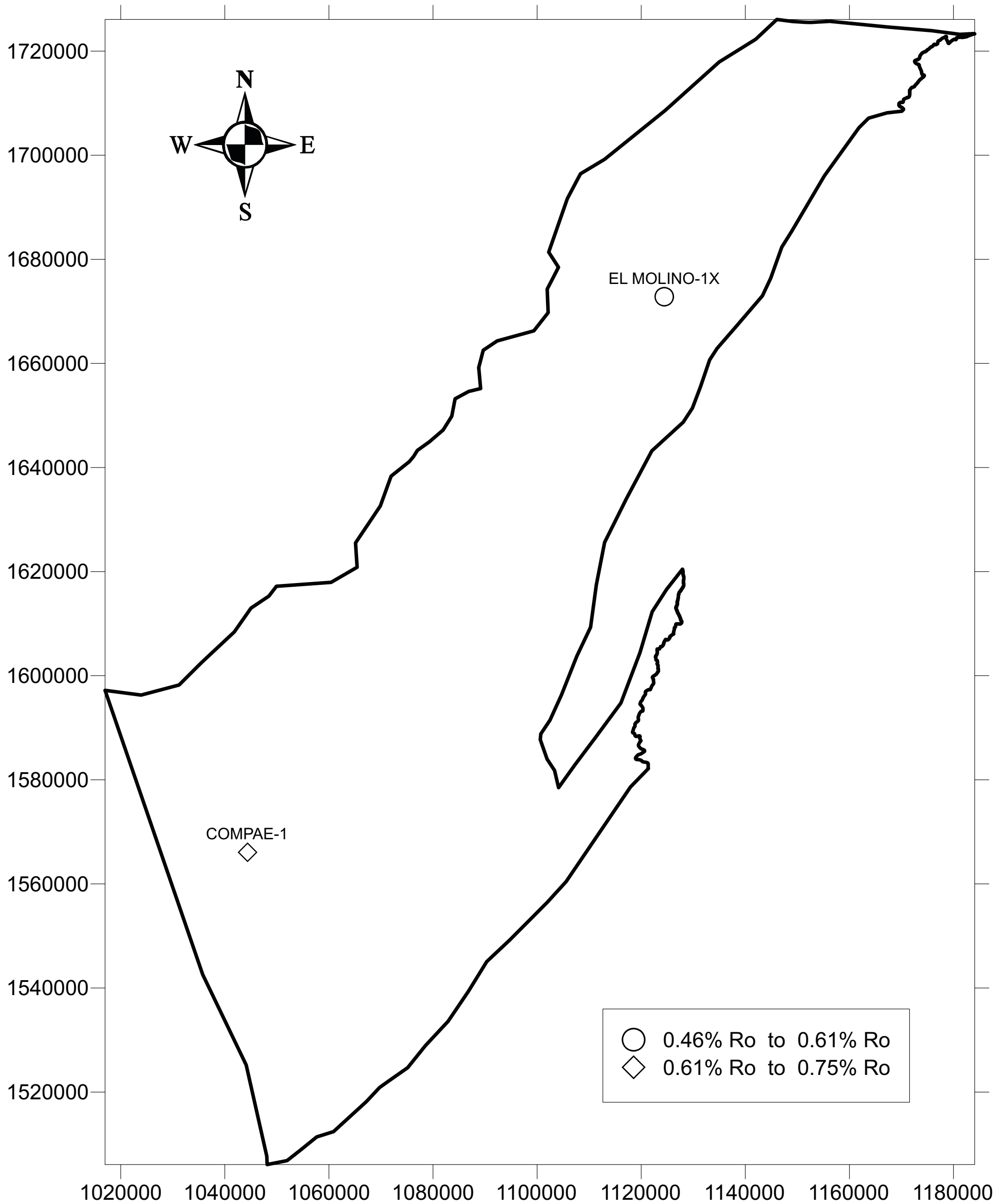
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from Cretaceous (Lagunitas, Aguas Blancas, La Luna, and Molino formations) and Cenozoic units (Los Cuervos Formation) with good to excellent oil generation potential (S2 up to 50 mg HC/g rock and % TOC up to 9). Additionally this graph shows that samples from the Cretaceous Lagunitas Formation and Cenozoic Los Cuervos Formation, although have good to excellent TOC values (up to 10 wt%), do not have good S2 values (< 5 mg HC/g rock), indicating that the kerogen in these formations is not labile and appropriate for liquid hydrocarbons generation (Figure A).

-The vitrinite reflectance (%Ro) information shows that many samples in the basin are mature or overmature at the Cesar A-1X and Compae-1 well locations to the south of the basin, and less mature at the El Molino-1X and El Paso-3 wells to the north. (Figure B).

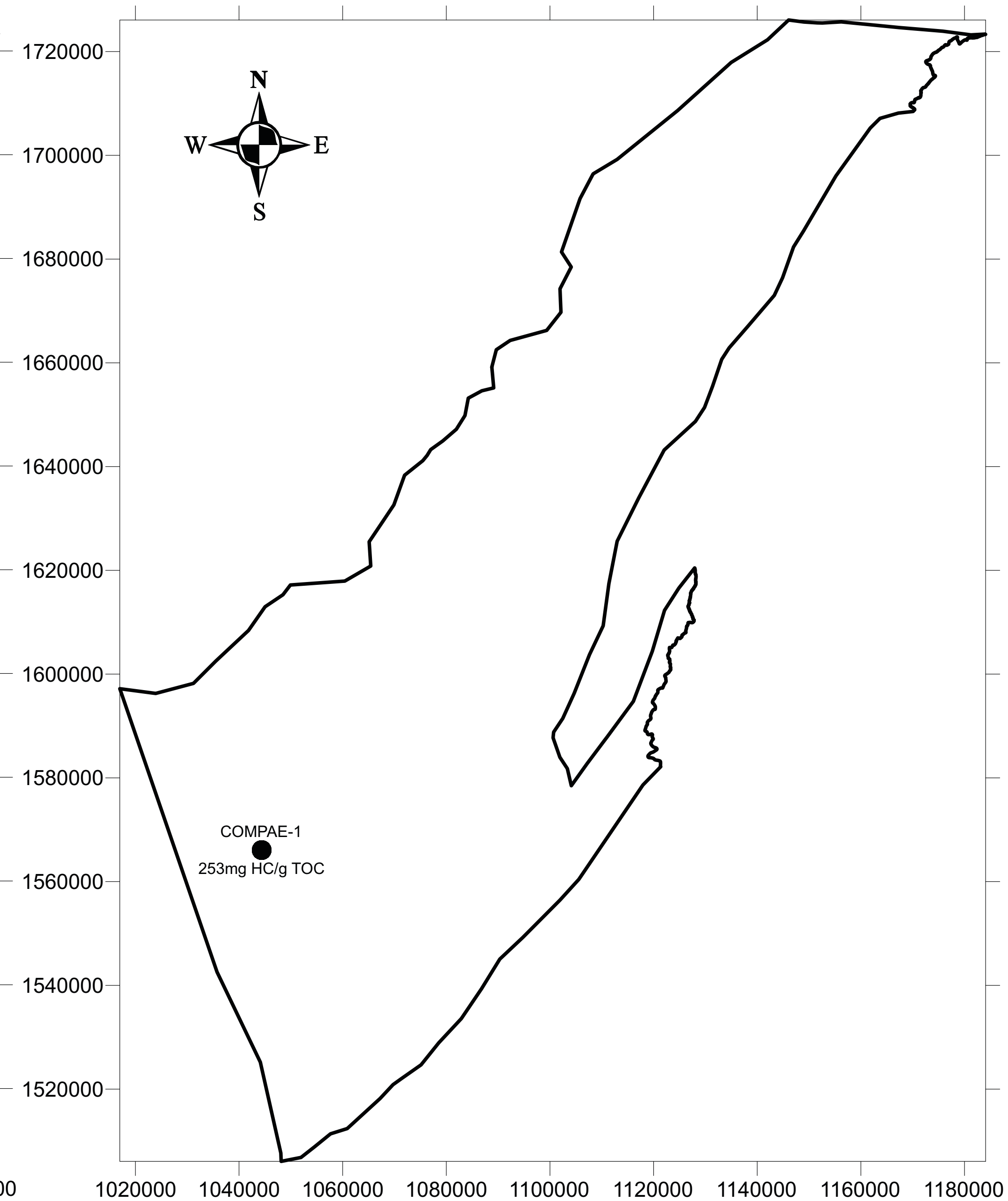
-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Cretaceous rocks of the Lagunitas,Aguas Blancas, La Luna and Molino formations and the Cenozoic rocks of the Los Cuervos formation. Maturity data indicate that the oil-prone formations are mature for hydrocarbons generation, and that good quality oils could be expected from the high thermal maturity reached by potential source rocks in the basin.

Source Rock Quality and Maturity Maps

La Luna Formation



Vitrinite Reflectance (%Ro)

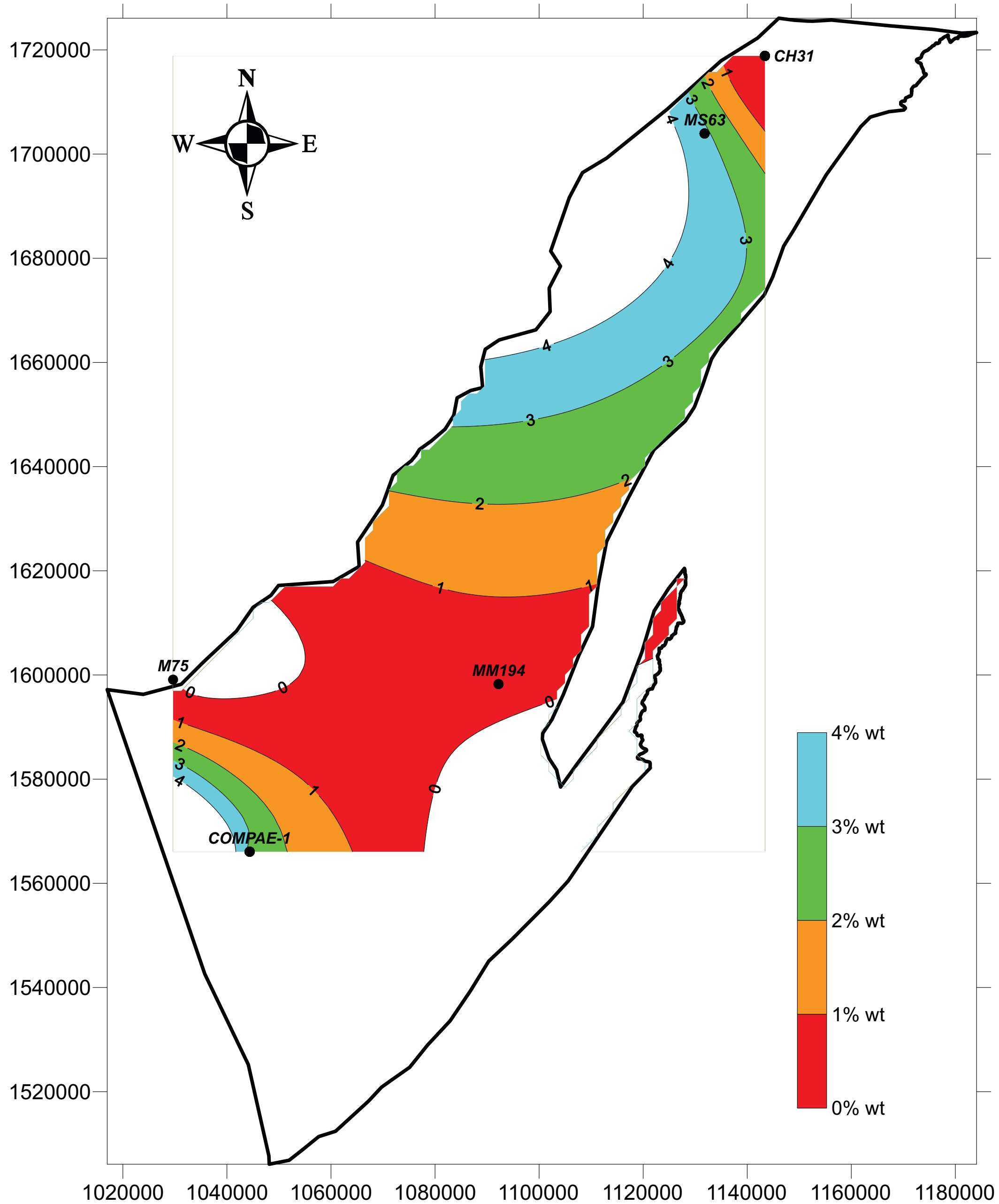


Hydrogen Index

Map datum: Magna Sirgas
Coord. origin: Bogotá

Source Rock Quality and Maturity Maps

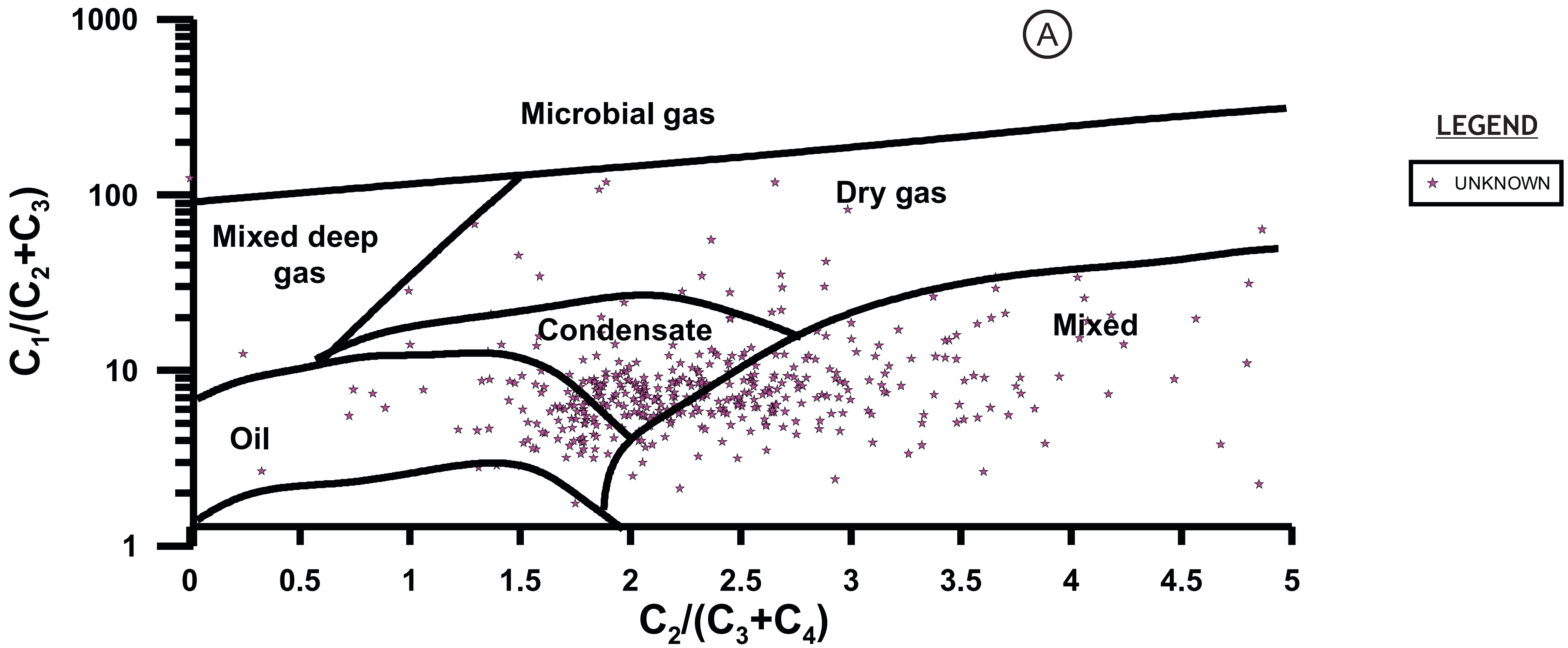
La Luna Formation

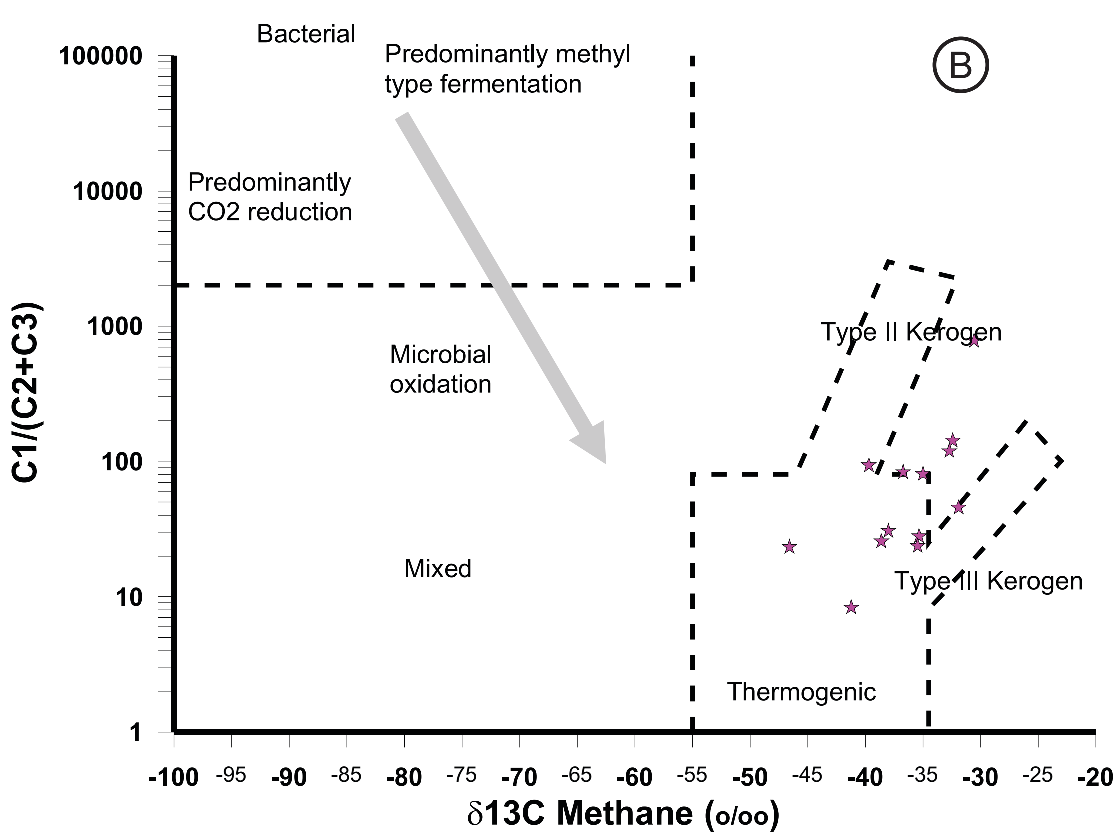


Organic Matter Content (TOC)

Map datum: Magna Sirgas
Coord. origin: Bogotá

Surface Geochemistry





Compositional data from surface geochemistry samples indicate that hydrocarbons are thermogenic, formed mainly during late oil generation window (condensates) with minor presence of high maturity hydrocarbons (gas generation window) with some mixing between different thermal maturity hydrocarbons.

Isotopic data indicates thermogenic generation from probably type II and type III kerogens

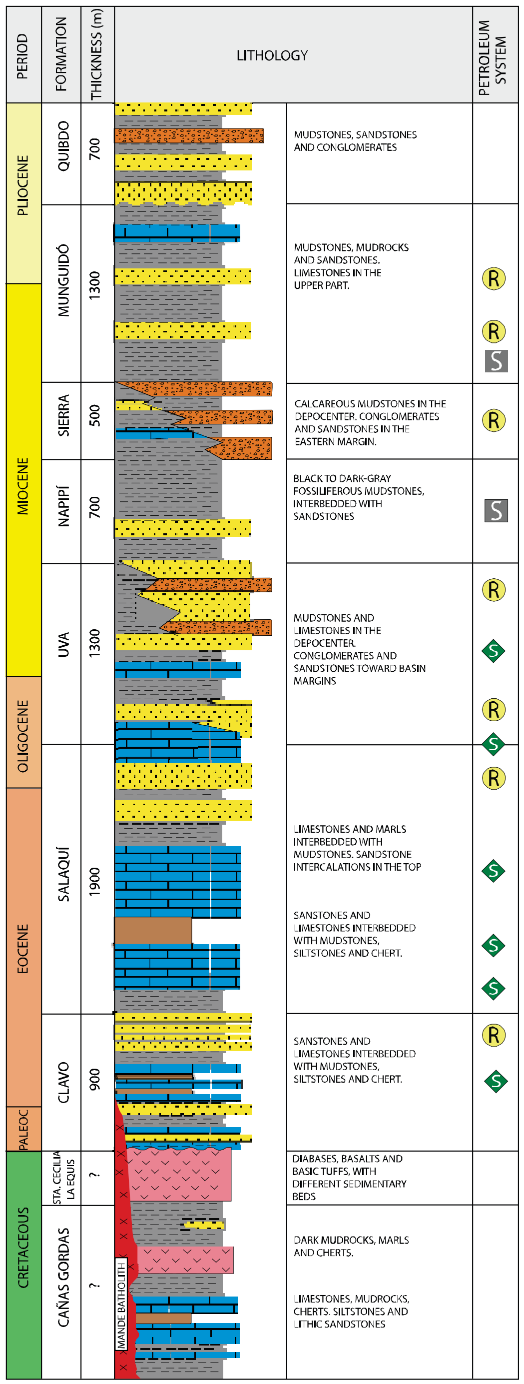
There is no evidence of microbial gas in the basin.

CHOCÓ BASIN

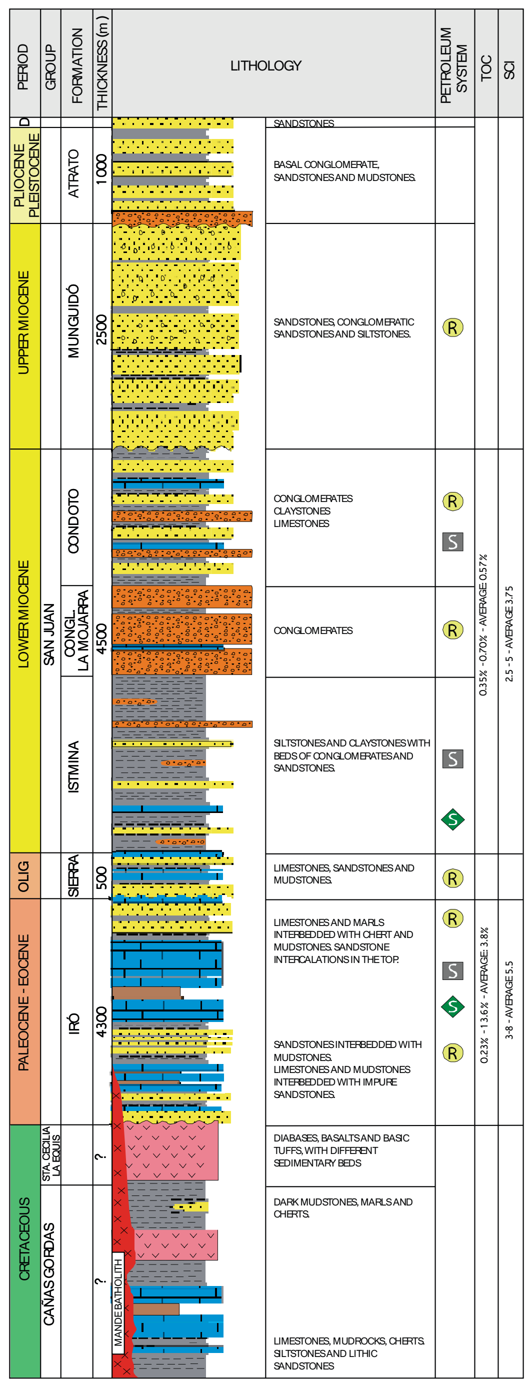
Generalities
Wells and Seeps
Source Rock Characterization
Surface Geochemistry

Generalities

Atrato Sub-Basin



San Juan Sub-Basin

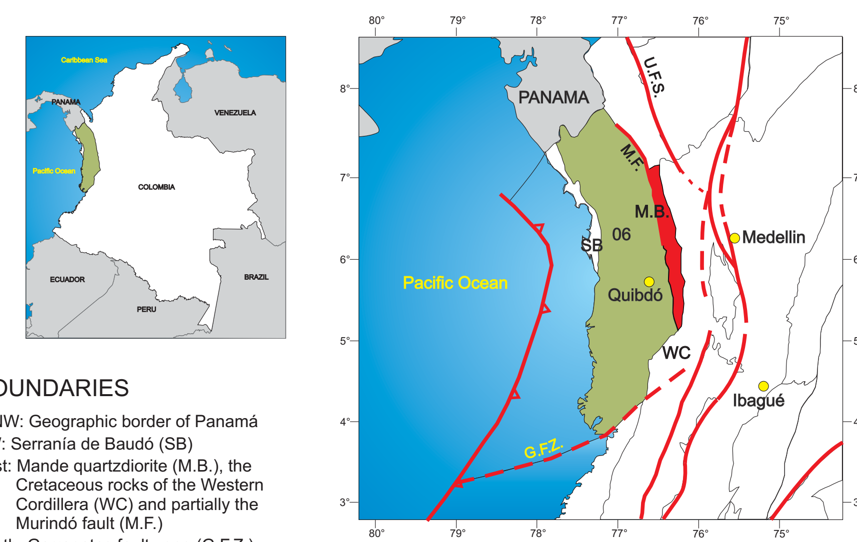


From Mojica et al.,, 2010

The source rock geochemical information interpreted for the Chocó Basin includes %TOC and Rock-Eval Pyrolysis data from 168 samples taken in 2 locations; additionally 68 organic petrography samples from 2 locations, and 333 surface geochemistry samples were interpreted.

Due to the lack of crude oil geochemical data, crude oil interpretation was not made for the basin.

CHOCÓ BASIN
LOCATION AND BOUNDARIES

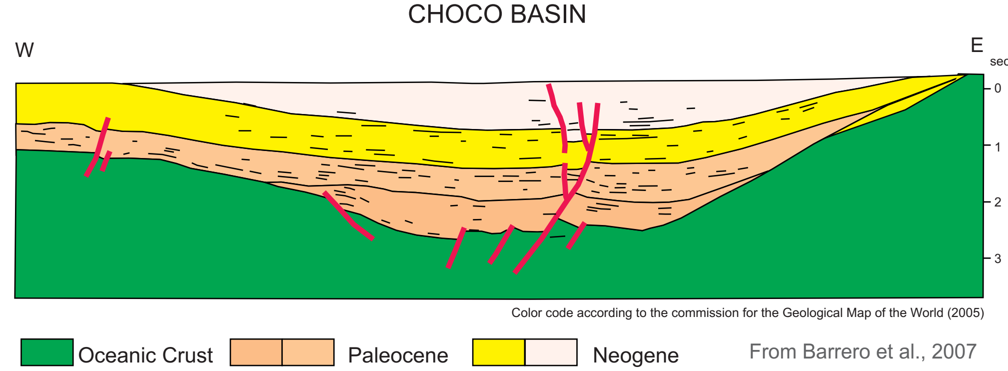


BOUNDARIES

N-NW: Geographic border of Panamá
NW: Serranía de Baudó (SB)
East: Mande quartzdiorite (M.B.), the Cretaceous rocks of the Western Cordillera (WC) and partially the Murindó fault (M.F.)
South: Garrapatas fault zone (G.F.Z.)
SW: Present Pacific coastline

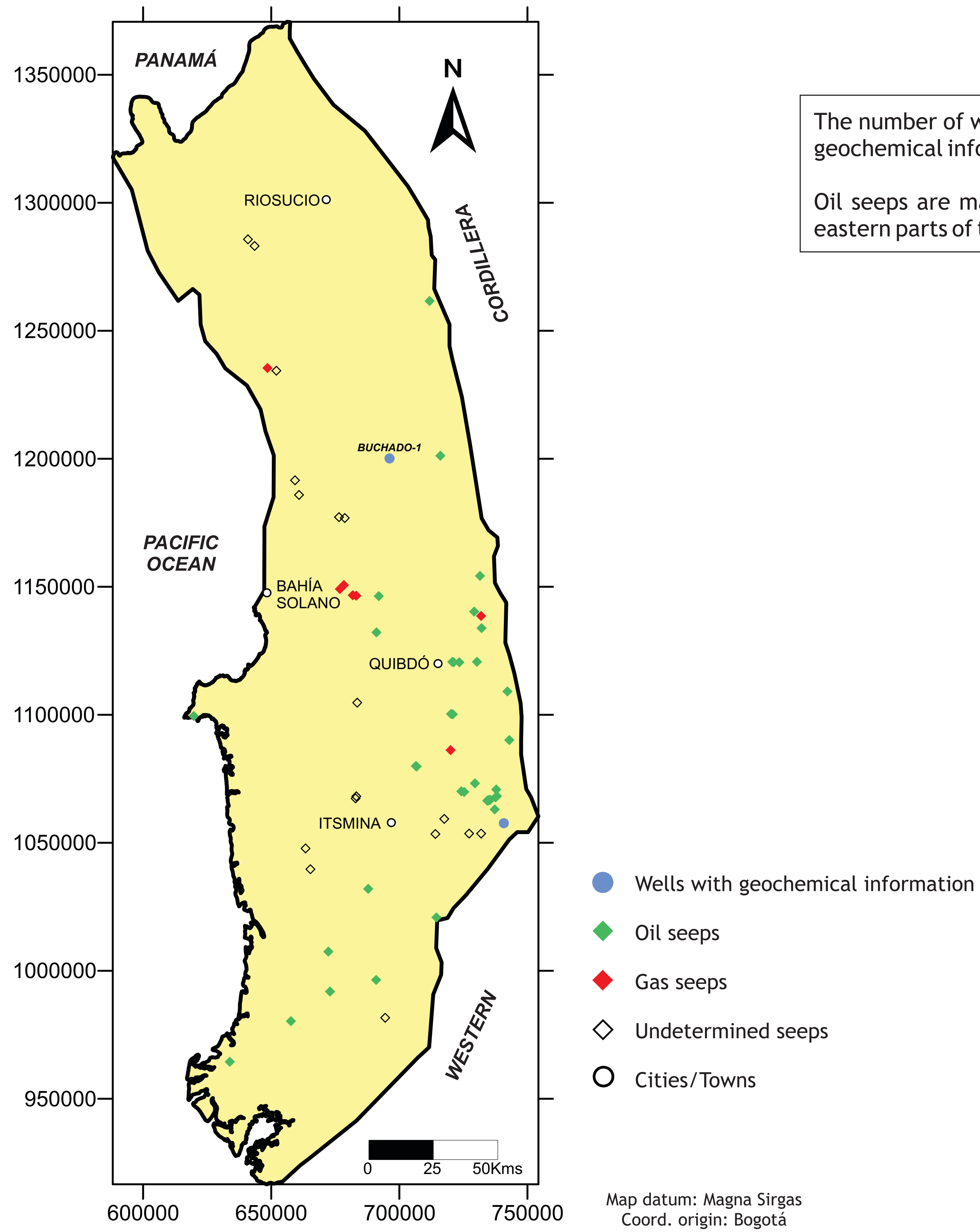
From Barrero et al., 2007

SCHEMATIC CROSS SECTION
CHOCO BASIN



From Barrero et al., 2007

Wells and Seeps

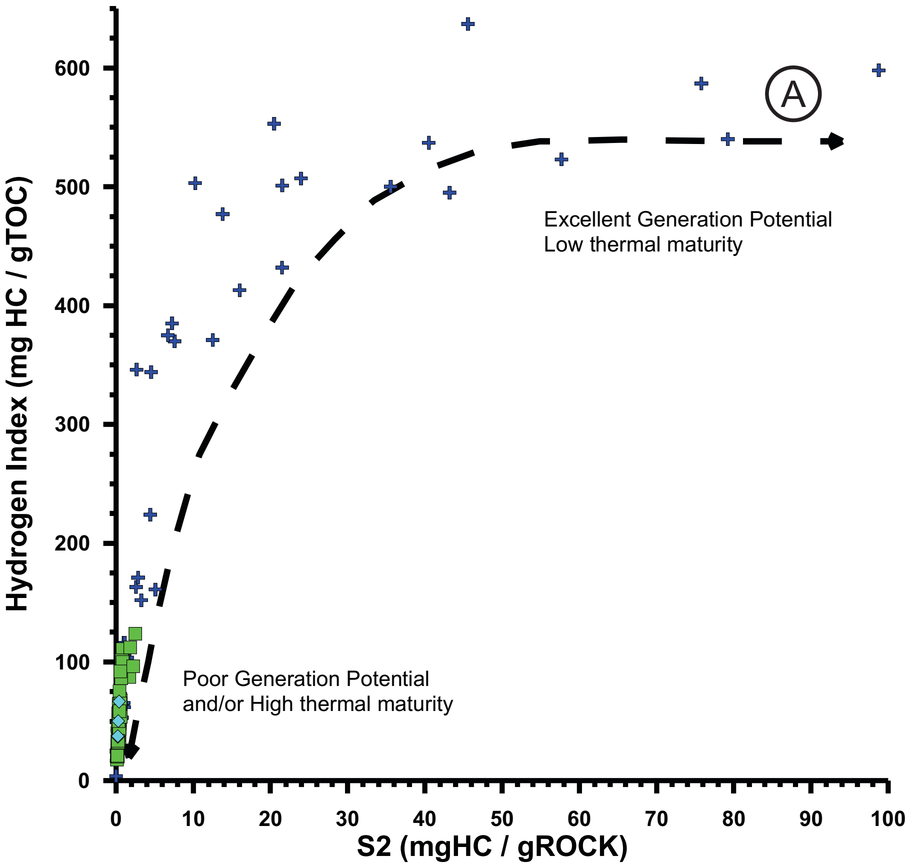


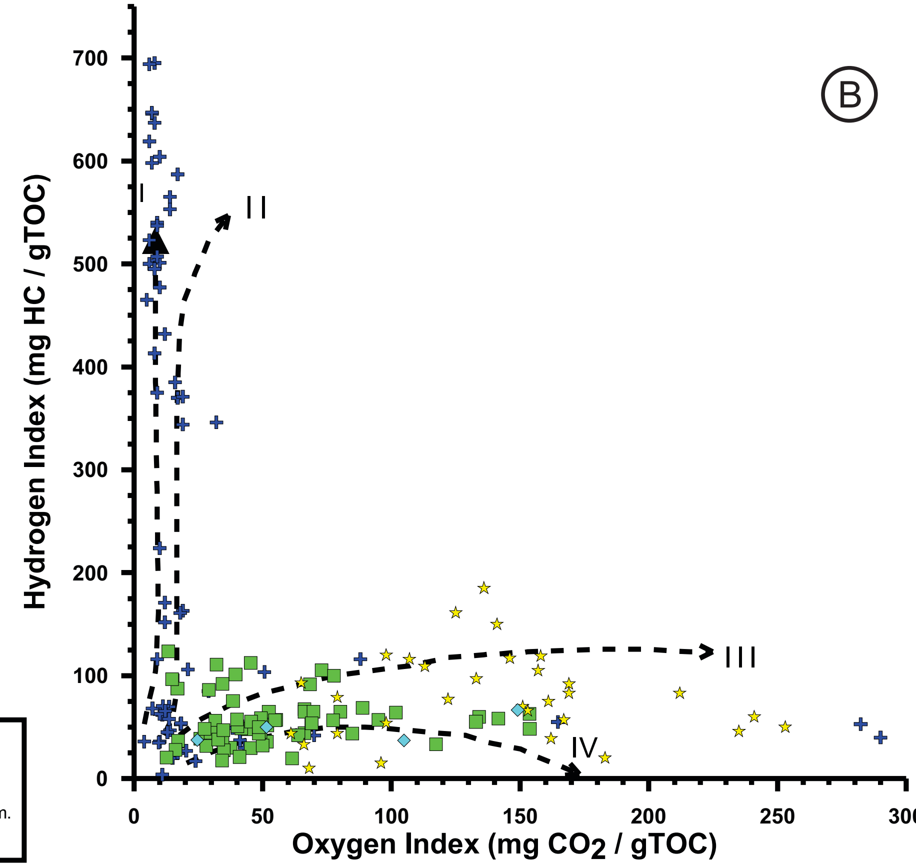
The number of wells and/or surface locations with geochemical information in the Chocó Basin is 2.

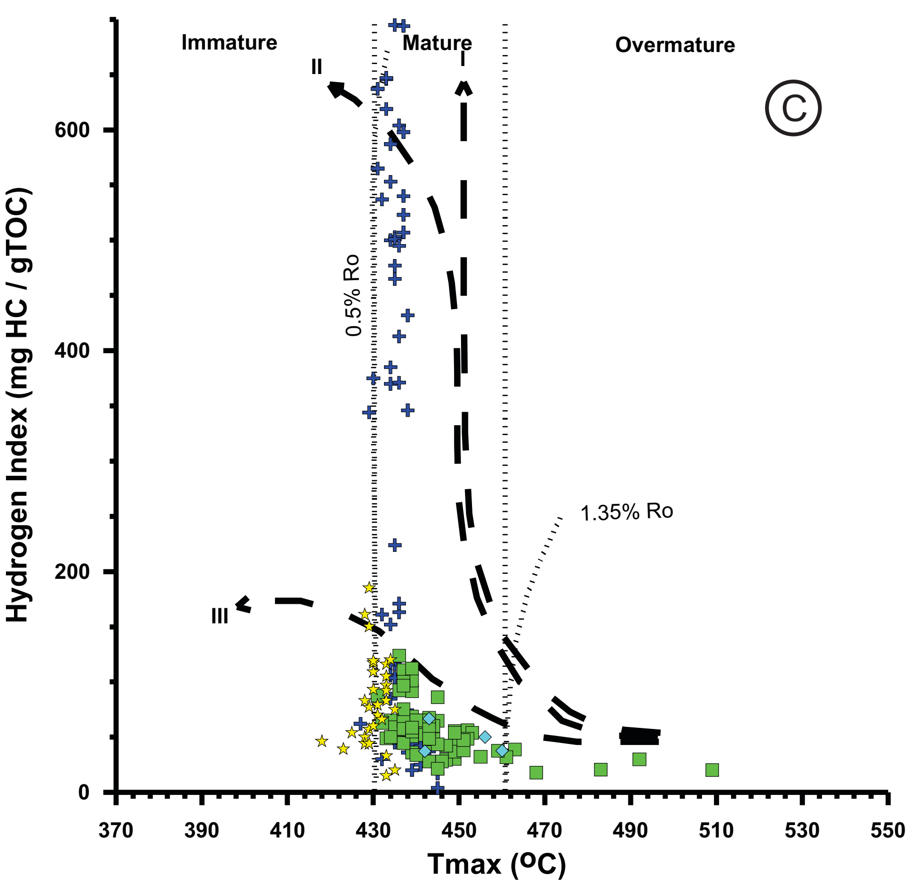
Oil seeps are mainly located at the southern and eastern parts of the basin.

Map datum: Magna Sirgas
Coord. origin: Bogotá

Source Rock Characterization





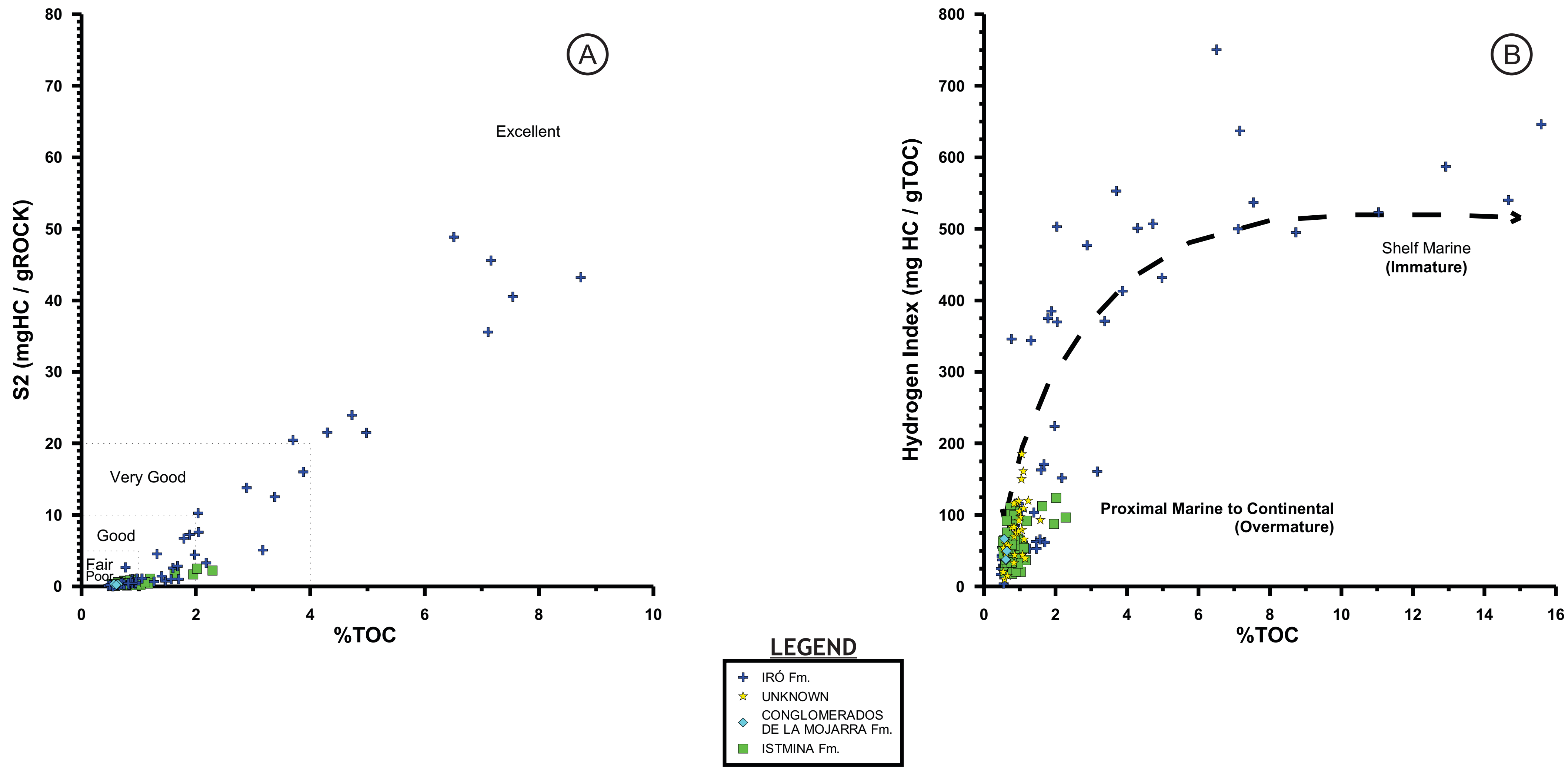


- The data obtained from pyrolysis of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Neogene Itsmina and Conglomerados de la Mojarra formations have poor generation potential (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock) but considering the high thermal maturity reached according to Tmax data, their present values could be evidence of organic content depletion, and samples from the Paleogene Iró Formation have good to excellent generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock). l (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Paleogene Iró Formation have type I and II oil-prone kerogens. In the case of the Neogene Itsmina and Conglomerado de la Mojarra formations their samples are indicative of type III gas-prone kerogen to type IV kerogen. (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that most samples from the Cenozoic units mentioned, have reached early maturity to overmature generation conditions in the basin, being the samples from the Itsmina Formation the most mature in the basin, and this high thermal maturity reached by these rocks could cause depletion in the organic content, giving low HI and S2 values. Considering this, it is very unlikely that these samples represent the real generation potential of these formations in the basin (Figure C).

Source Rock Characterization

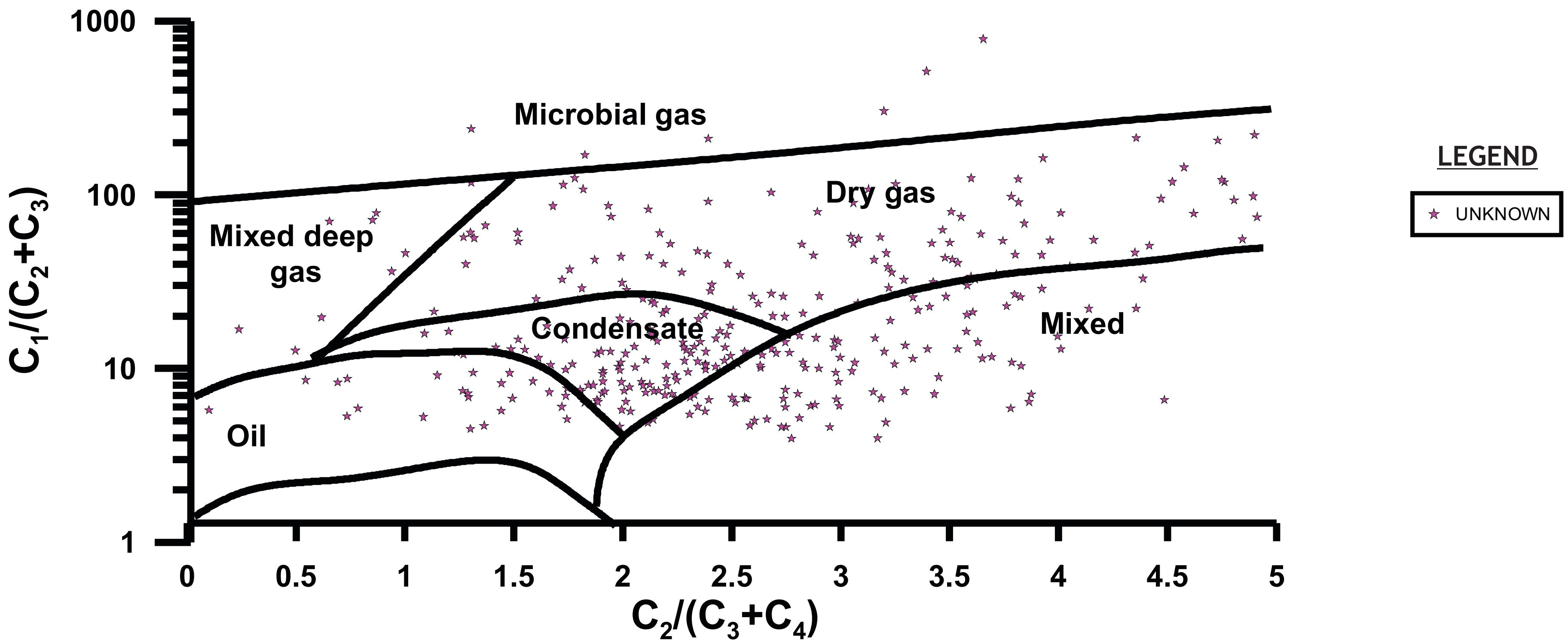


- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from the Iró Formation with good to excellent oil generation potential (S2 up to 50 mg HC/g rock and % TOC up to 9) (Figure A).

- The Hydrogen Index vs Organic content (%TOC) graph shows that samples from the Iró Formation have the best source rock characteristics (HI values > 300 mg HC/g TOC and %TOC > 2), which are typical from rocks deposited in shelf marine environments. Again the low HI and %TOC values for the samples of the Itsmina Formation could be affected by the high thermal maturity reached by this unit, and the data could not be reliable to determine the depositional conditions of the source rock(Figure B).

-In summary, the best source rock at the basin, with good to excellent oil generation potential intervals is the Paleogene Iró Formation. However, the high thermal maturity reached by the Neogene Itsmina and Conglomerados de la Mojarra formations precludes discarding these units as good oil sources in the basin. Additionally the thermal maturity data suggests that all these units have reached maturity for good quality hydrocarbons generation in the basin.

Surface Geochemistry



Compositional data from surface geochemistry samples indicate that the hydrocarbons are thermogenic, formed mainly during late oil generation window (condensates) with minor presence of high maturity hydrocarbons (gas generation window).

Mixing between different thermal maturity hydrocarbons is also indicated by the data.

There are very few samples of microbial gas to consider biogenic gas an important process in the basin.

EASTERN CORDILLERA BASIN

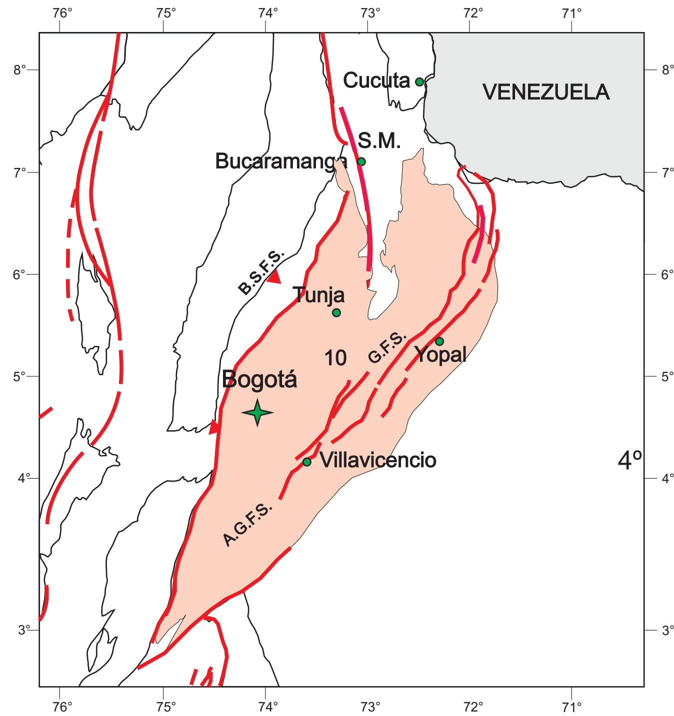
Generalities
Wells and Seeps
Crude Oil Quality
Source Rock Characterization
Surface Geochemistry
Petroleum Systems (Crude-Rock Correlations)

Generalities

The source rock geochemical information interpreted for the Eastern Cordillera Basin includes %TOC and Rock-Eval Pyrolysis data from 1512 samples taken in 9 locations; additionally 369 organic petrography samples from 8 locations were interpreted.

Crude oil and extracts information from 4 bulk analysis samples, 111 liquid chromatography samples, 114 gas chromatography samples, 125 biomarker sample,42 isotopes and 349 surface geochemistry samples were also interpreted.

EASTERN CORDILLERA BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

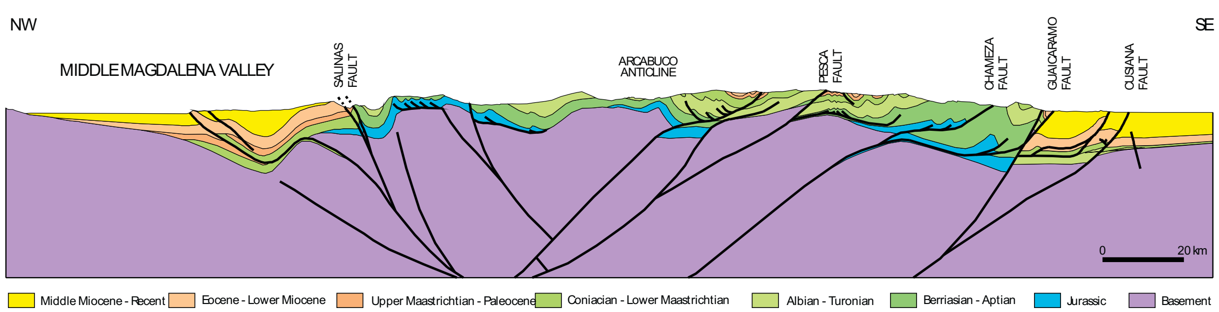
North: Igneous and metamorphic rocks from the Santander massif (S.M.)

East: frontal thrust system of the Eastern Cordillera

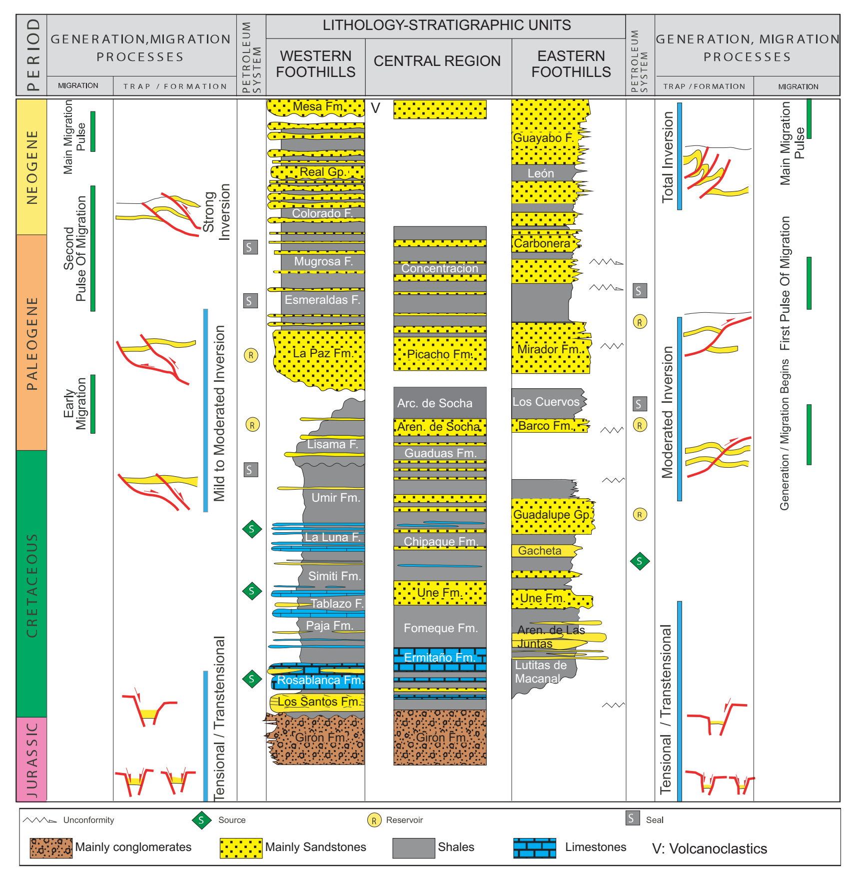
South: Algeciras-Garzón Fault System (A.G.F.S.)

West: Bituima and La Salina Fault System (B.S.F.S.)

From Barrero et al., 2007

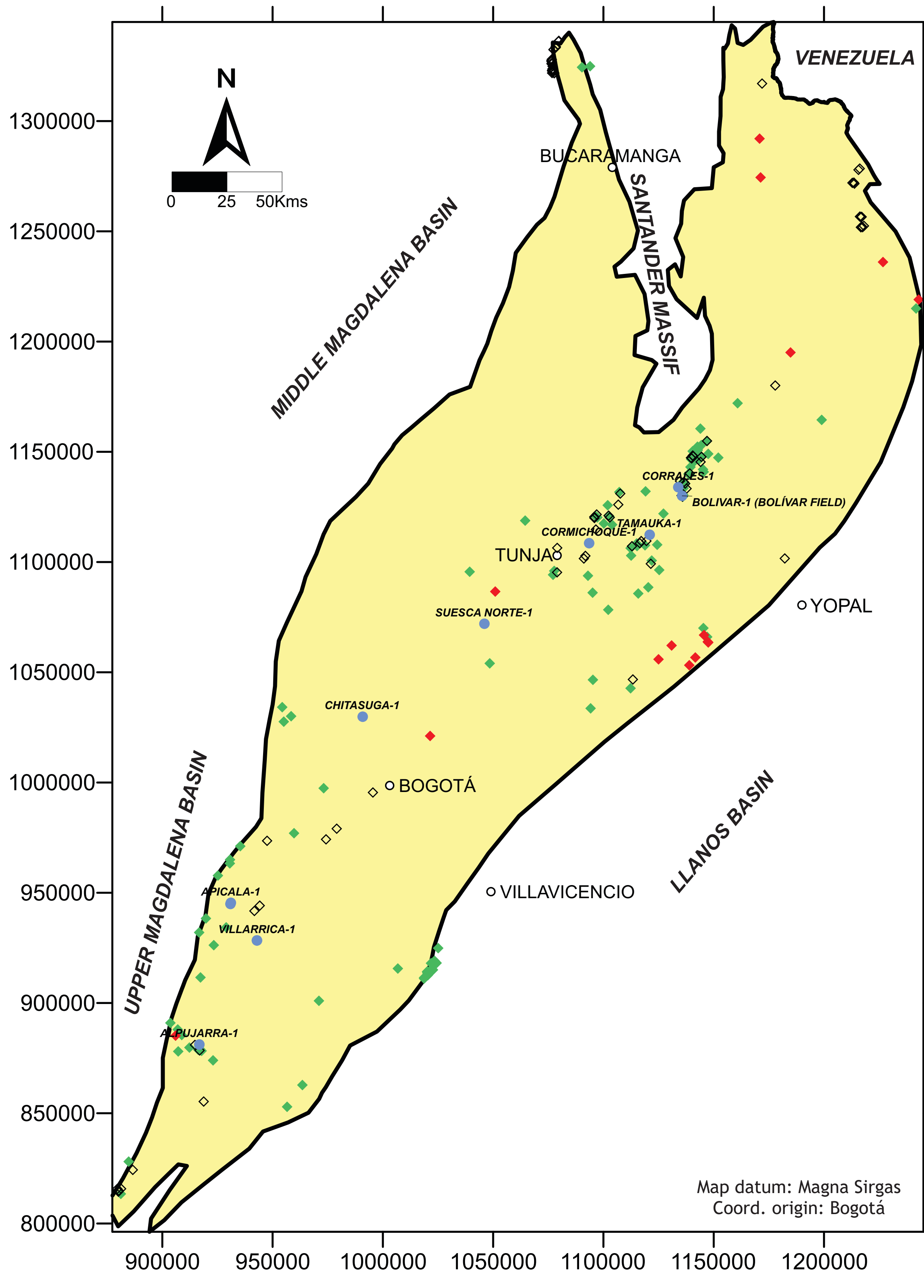


Modified from Cooper et al., 1995



From Barrero et al., 2007

Wells and Seeps

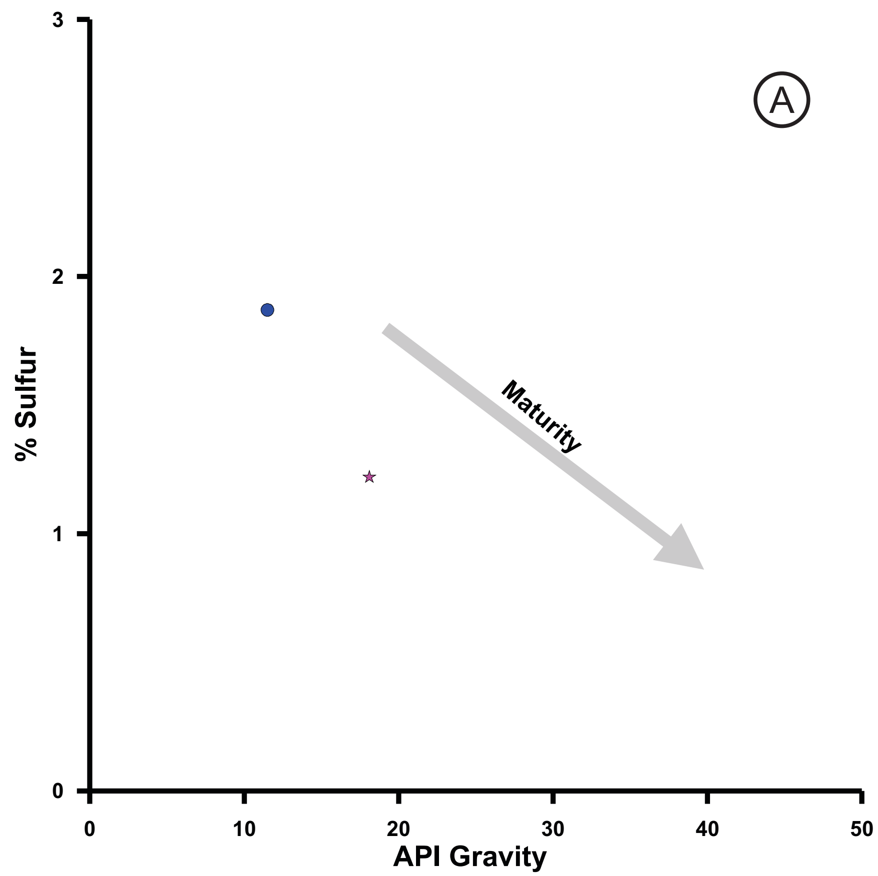


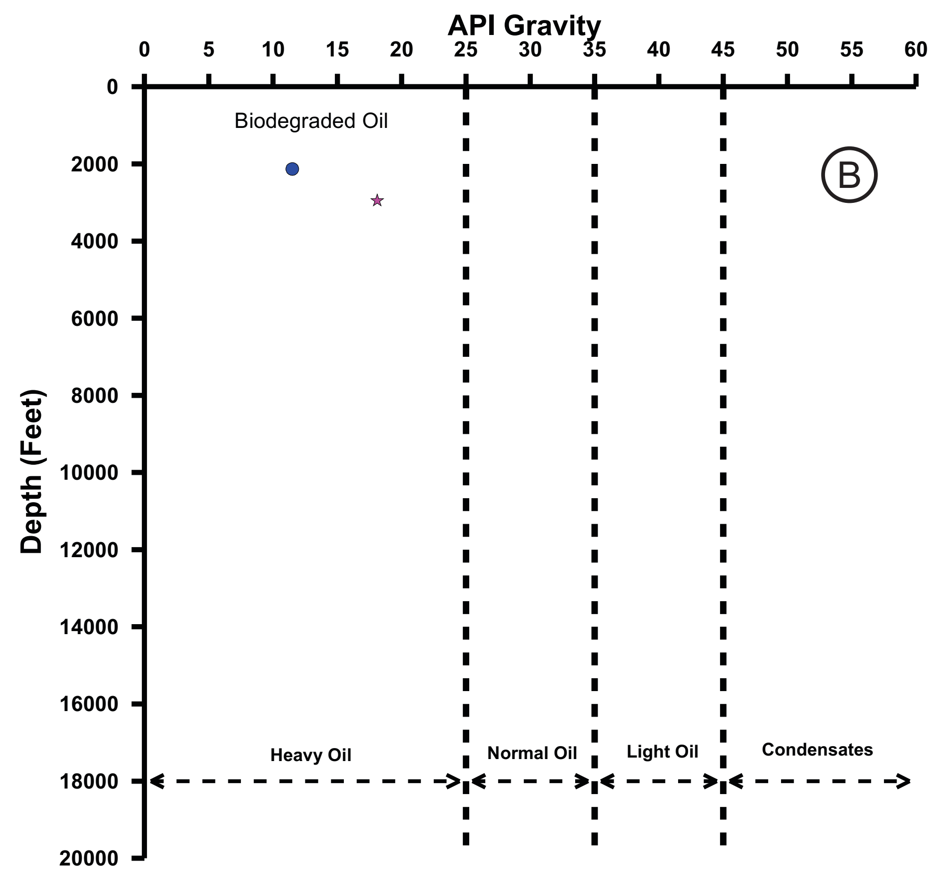
The number of wells and/or surface locations with geochemical information in the Eastern Cordillera Basin is 12 .

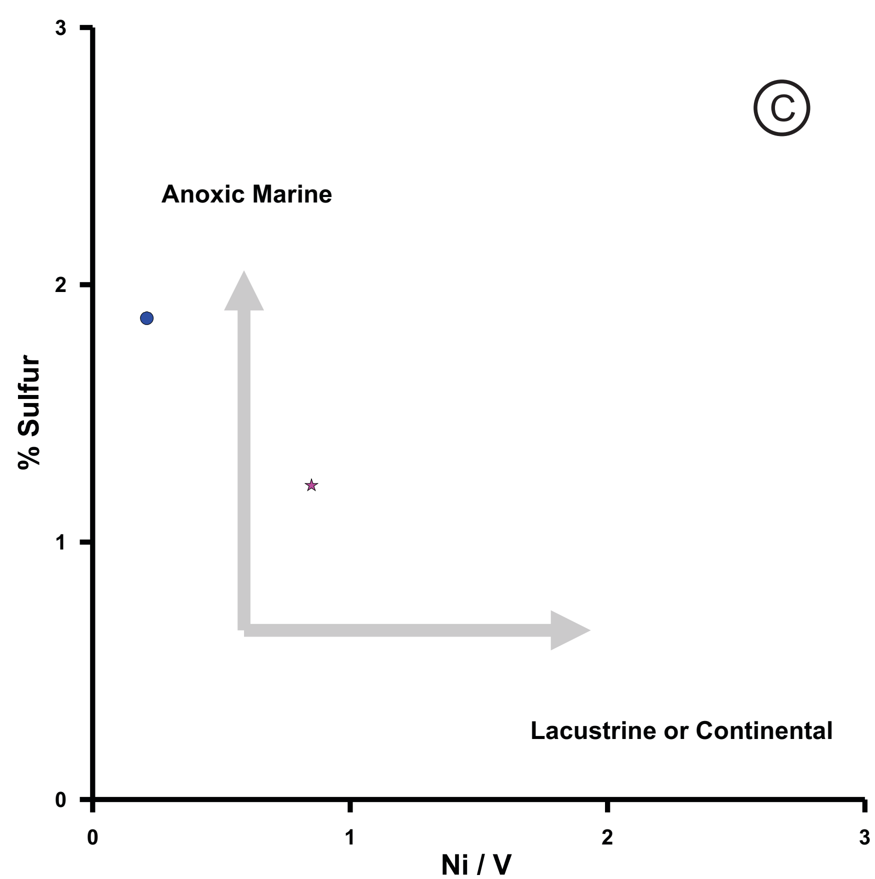
Oilseeps are located widespread all over the basin

- Wells with geochemical information
- Oil seeps
- Gas seeps
- Undetermined seeps
- Cities/Towns

Crude Oil Quality





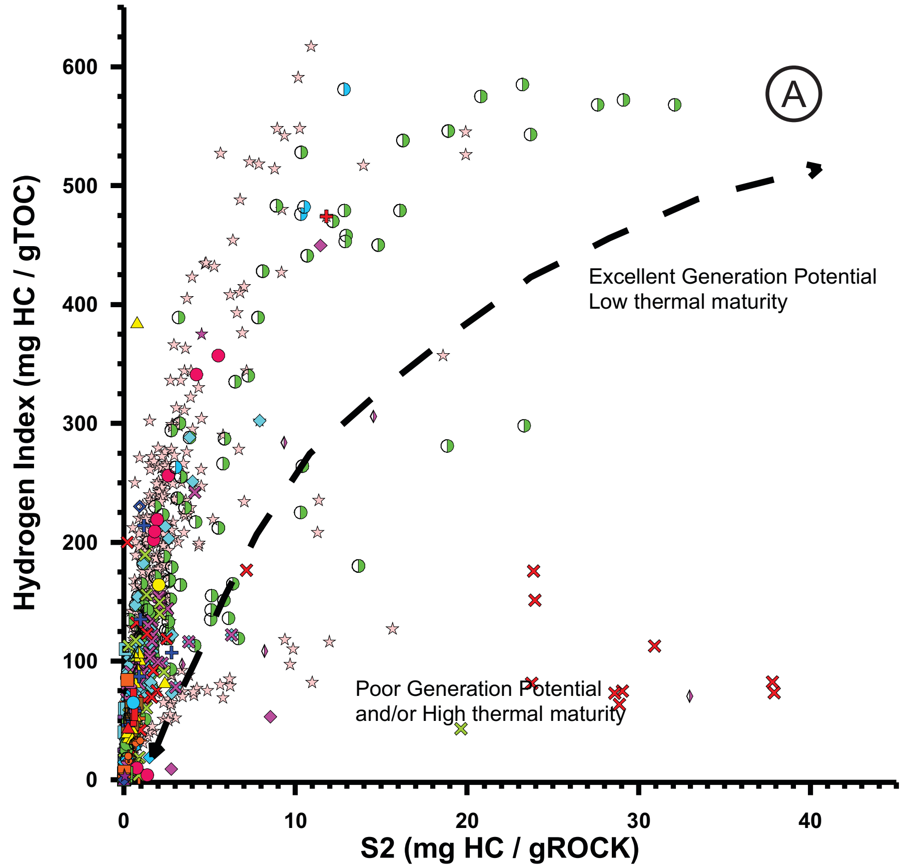


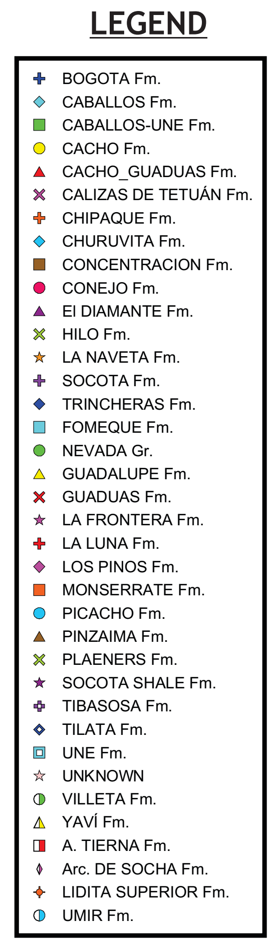
- Heavy oils with API gravities below 20° and sulfur content above 1% are present in the basin. There is correlation between sulfur and API gravity, indicating that the higher the API gravity the lower the sulfur content and hence crude oil quality (Figure A).

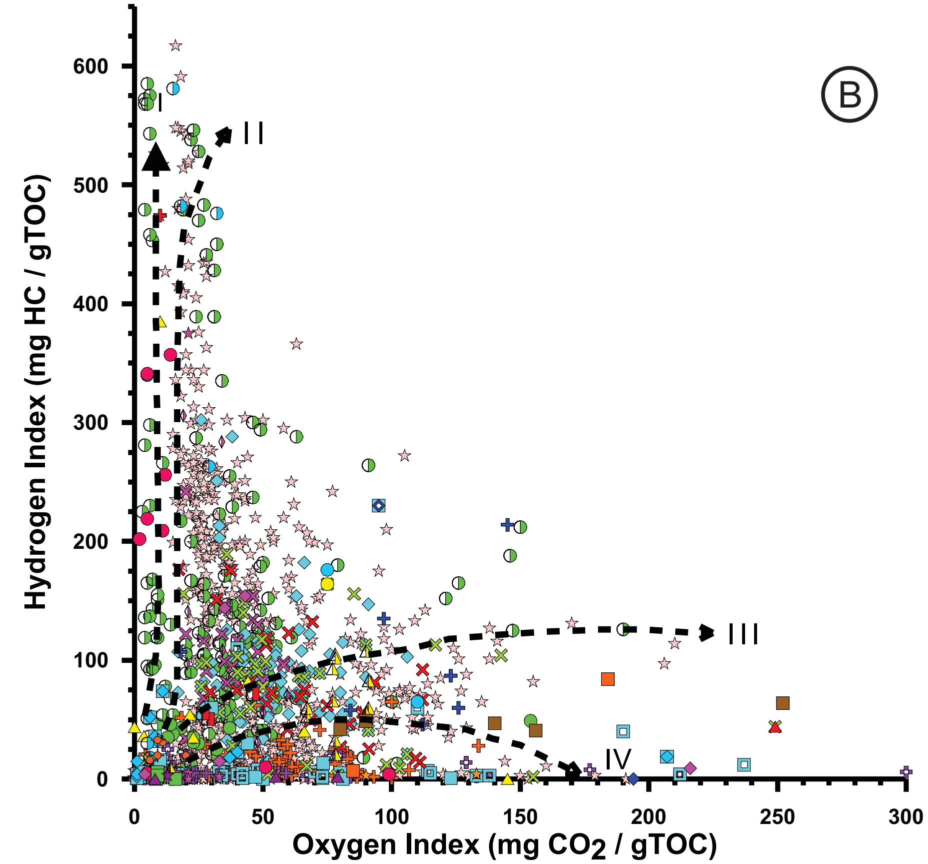
- The few crude oils reported in the basin suggests that API gravity should increase with depth and that hydrocarbons could be found relatively shallow in the basin (Figure B).

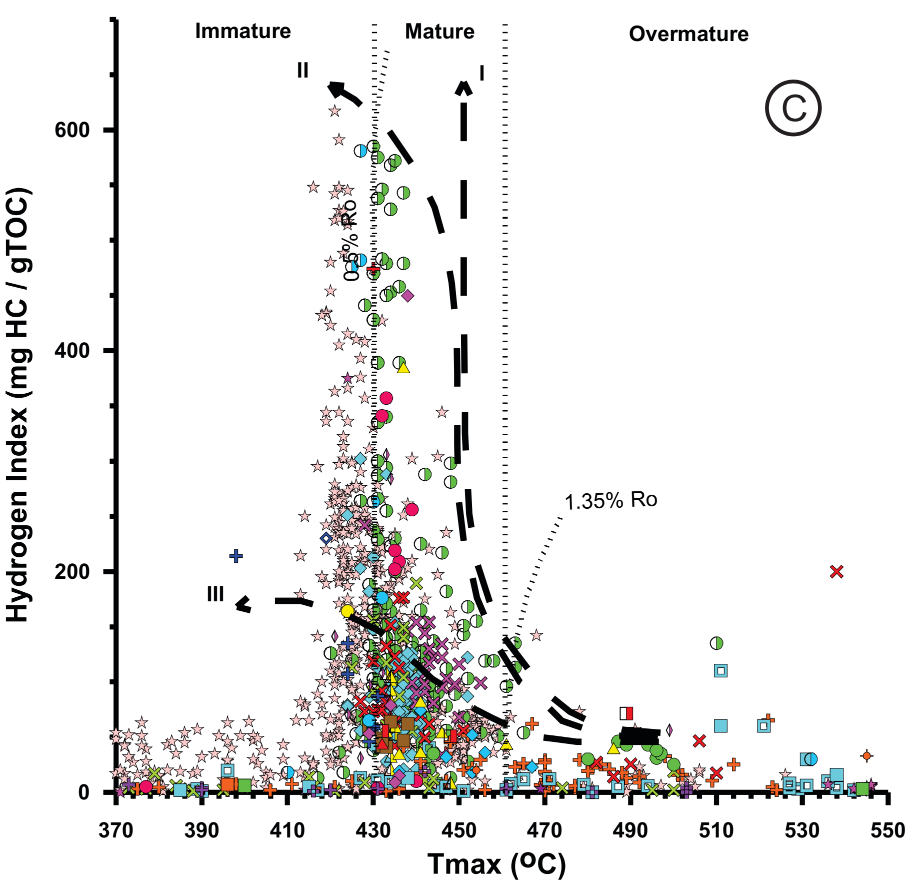
- The sulfur content of the oils is above 1%, and its Ni/V ratio below 1, suggesting that they are produced from rocks deposited in a marine suboxic to anoxic environment (Figure C).

Source Rock Characterization







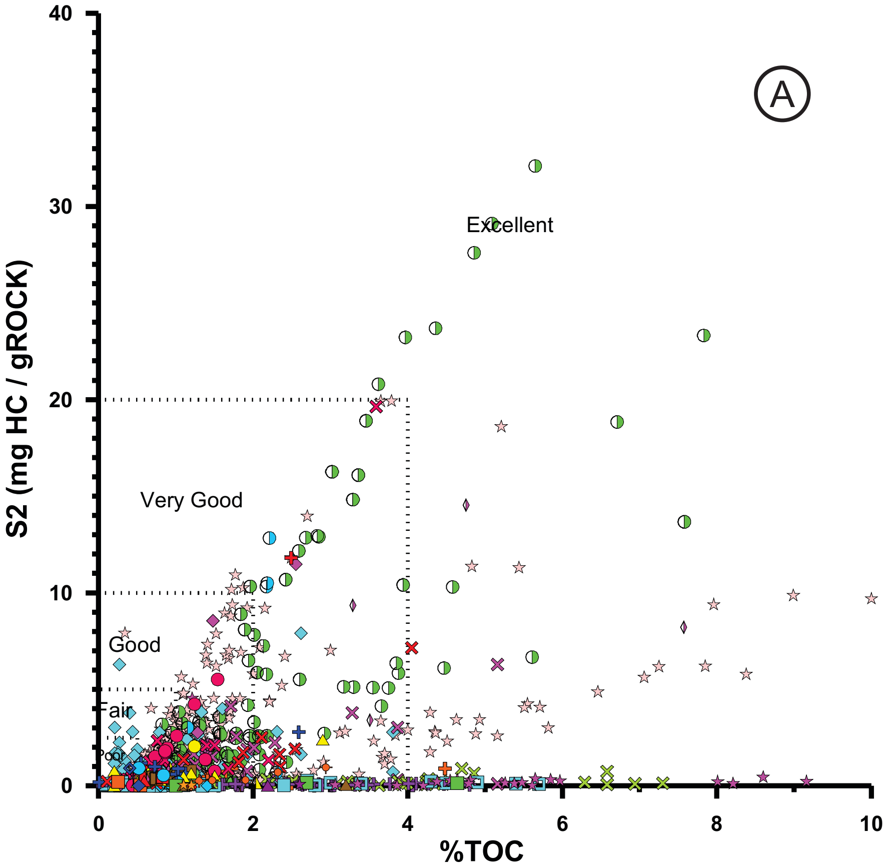


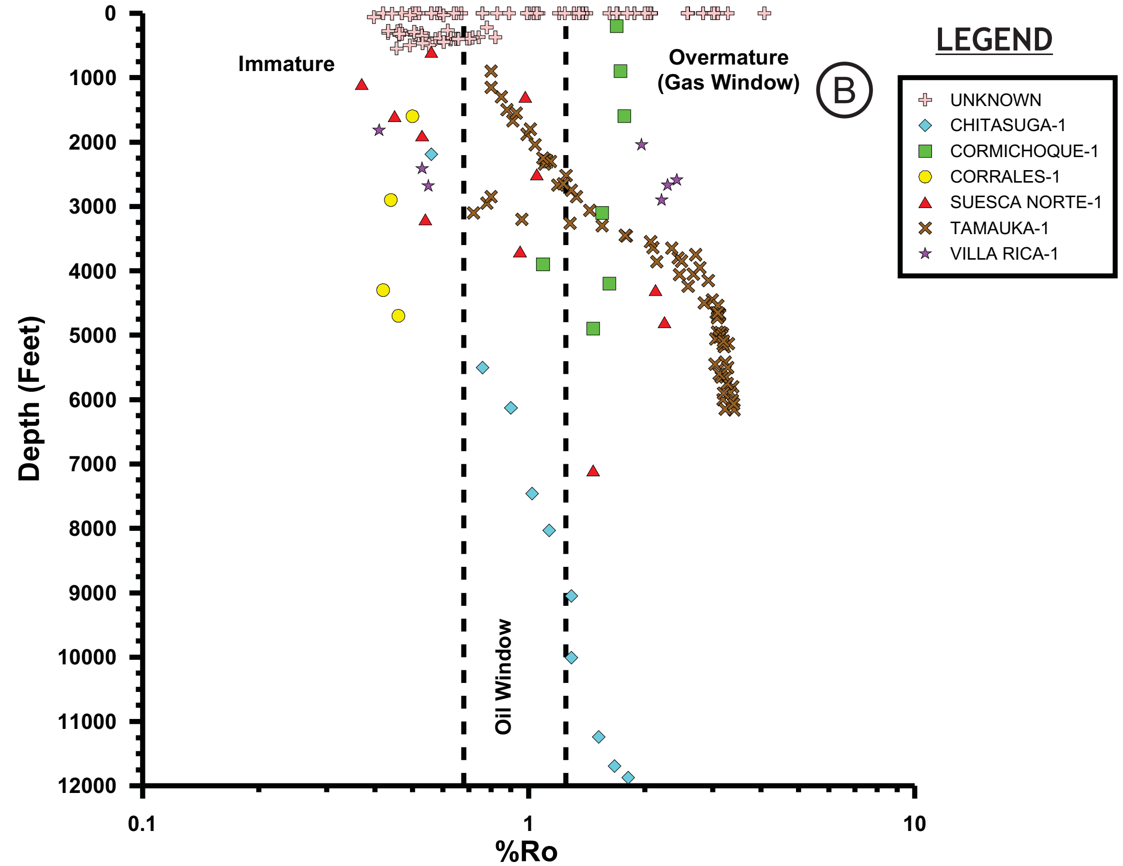
- The data obtained from pyrolysis Rock-Eval of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Cretaceous Caballos, Conejo, La Luna, Villeta, Guadalupe, Los Pinos and Umir formations and the Cenozoic Arcillas de Socha Formation have good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock). It is important to consider that these and other units with source rock characteristics, are or were deeply buried in the basin by thrusting, and the poor generation values obtained from many samples could reflect the depletion effect caused by the high thermal maturity reached by these rocks in sub-thrust sheets (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cretaceous Caballos, Conejo, La Luna, Villeta and Umir formations have type II oil-prone kerogen. There are also samples from these formations with type III gas-prone characteristics. In the case of the Cenozoic units (Guaduas, Concentración and Bogotá formations) their samples are indicative of type III gas-prone kerogen to type IV kerogen. (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples from the Cretaceous to Cenozoic units mentioned, have reached early maturity to overmature conditions in the basin. Being the samples from the Cretaceous Fomeque, Chipaque and Hiló formations the more mature in the basin (Figure C).

Source Rock Characterization



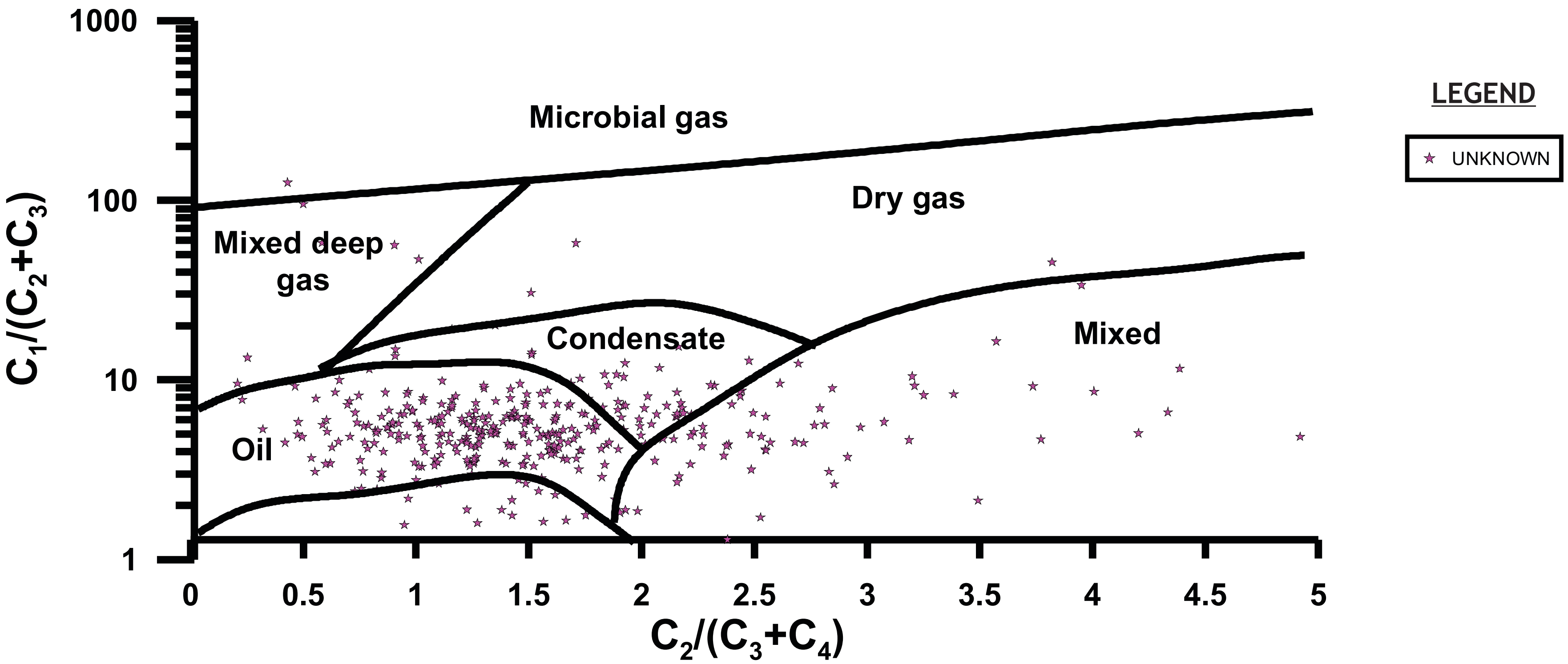


- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from Cretaceous units (Caballos, Villeta, La Luna, and Umir) and the Cenozoic Arcillas de Socha Formation, with good to excellent oil generation potential (S2 up to 50 mg HC/g rock and % TOC up to 9) (Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence is mature to overmature in the basin. With variable maturity trends caused probably by different burial and thermal histories controlled by the structural development of the Eastern Cordillera (Figure B).

-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Cretaceous rocks of the Caballos, Conejo, La Luna, Villeta and Umir formations and the Cenozoic Arcillas de Socha Formation. Tmax maturity data indicates that the Cretaceous oil-prone formations are mature and that the high thermal maturity reached by some source rocks, could produce crude oil with better characteristics than that already found, and depleted or exhausted some source rocks in the basin.

Surface Geochemistry

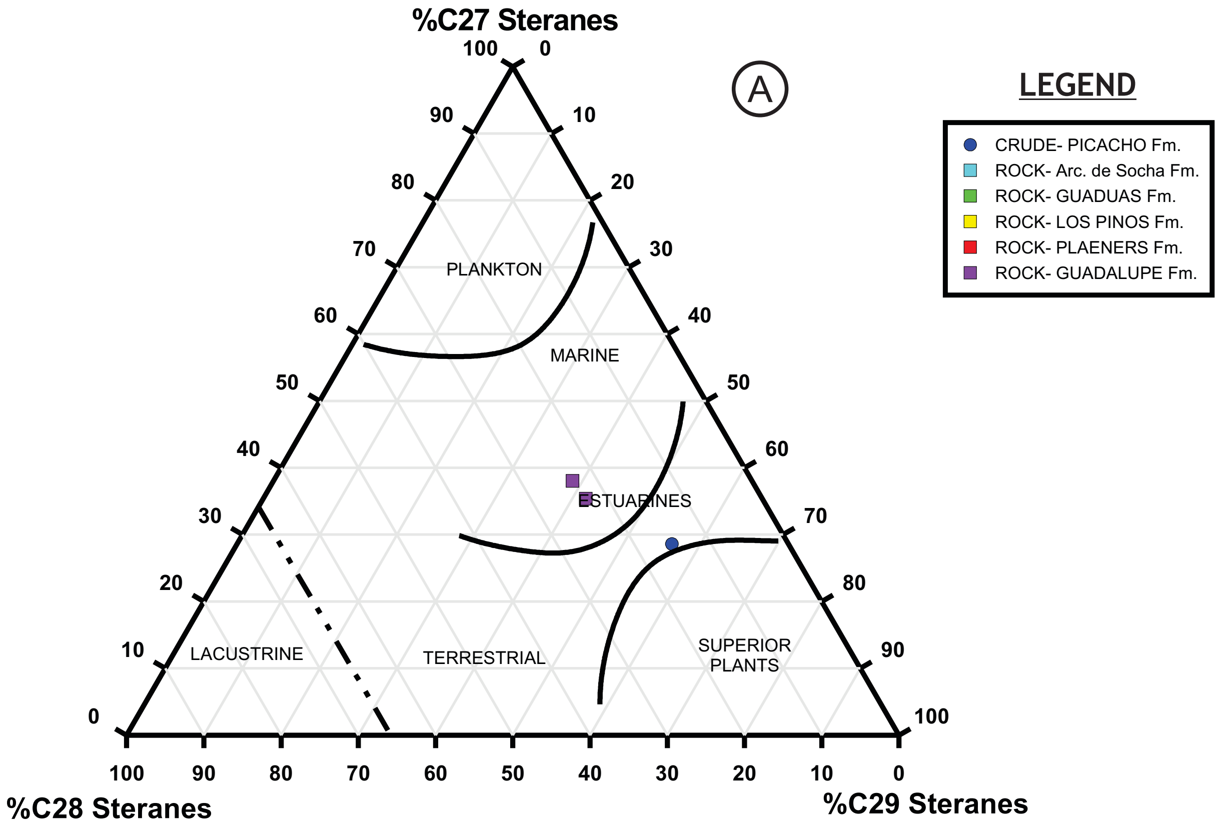


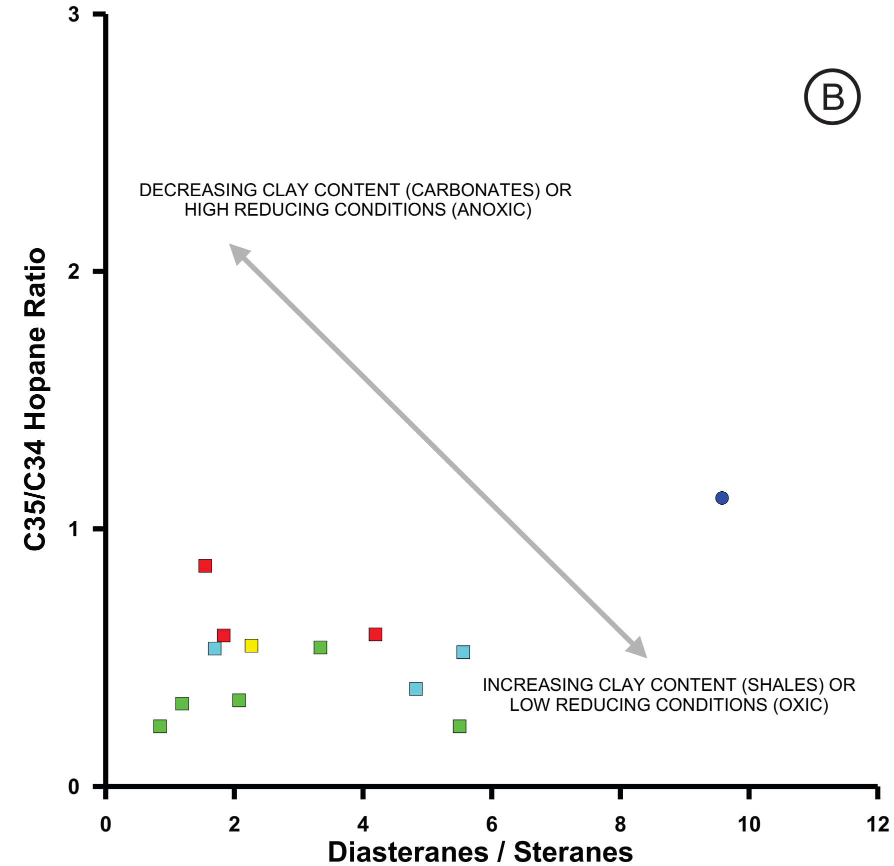
Compositional data from surface geochemistry samples indicate that hydrocarbons are thermogenic, formed mainly during oil generation window with minor presence of high maturity hydrocarbons (gas generation window).

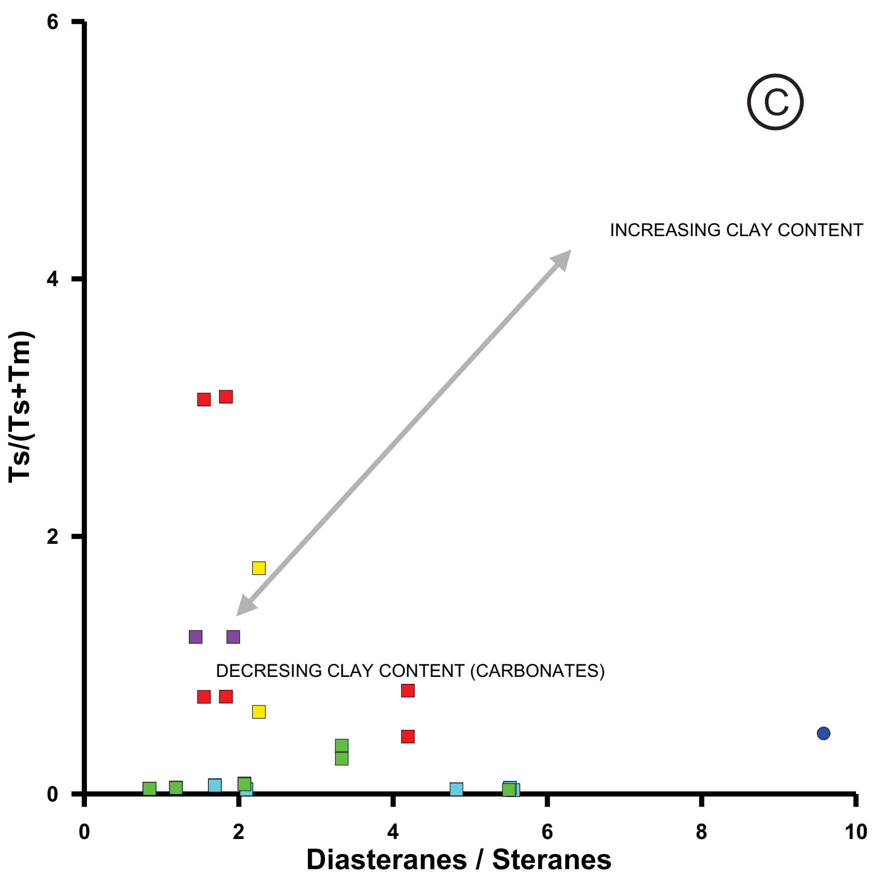
Mixing between different thermal maturity hydrocarbons is also indicated by the data.

There is no evidence of microbial gas in the basin.

Petroleum Systems (Crude-Rock Correlations)







Crude - Rock correlations from samples at the basin suggest the following:

- There is no good correlation between the few crude and extracts data available for the basin. The crude in the Picacho Formation has higher C29 steranes concentration than the rock extracts from the Guadalupe Formation, indicating more terrestrial organic matter input (Figure A).

- The C35/C34 Hopanes, Ts/(Ts+Tm) and diasteranes/steranes indicate that the rock extracts correspond to poor-clay rocks probably carbonatic deposited under low reducing conditions (Figures B and C).

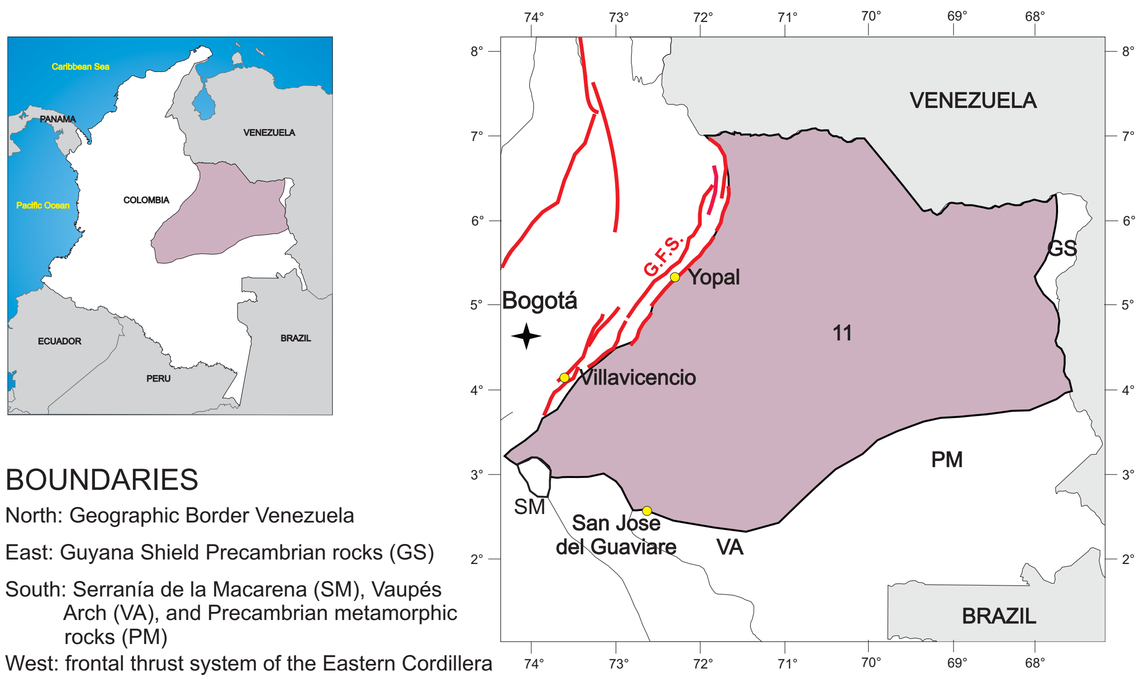
- This lack of correlation precludes a better determination of the active petroleum systems in the basin, however the existence of hypothetical petroleum systems can be stated from existing geochemical and geological information as follows: Los Pinos - Guadalupe (.), Villeta/La Luna - Guadalupe (.), Chipaque - Monserrate (.), Tibasosa - Une (.).

EASTERN LLANOS BASIN

Generalities
Wells and Seeps
Crude Oil Quality
Depositional Environments
Chromatography
Source Rock Characterization
Source Rock Quality and Maturity Maps
Gas Characterization
Surface Geochemistry
Petroleum Systems (Crude-Rock Correlations)

Generalities

EASTERN LLANOS BASIN
LOCATION AND BOUNDARIES

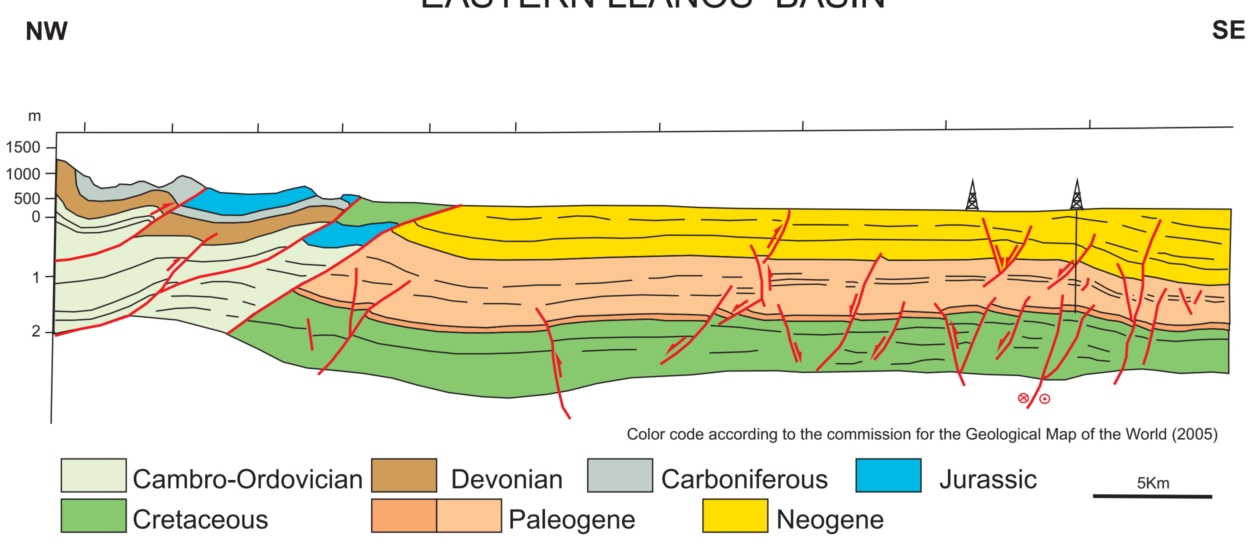


From Barrero et al., 2007

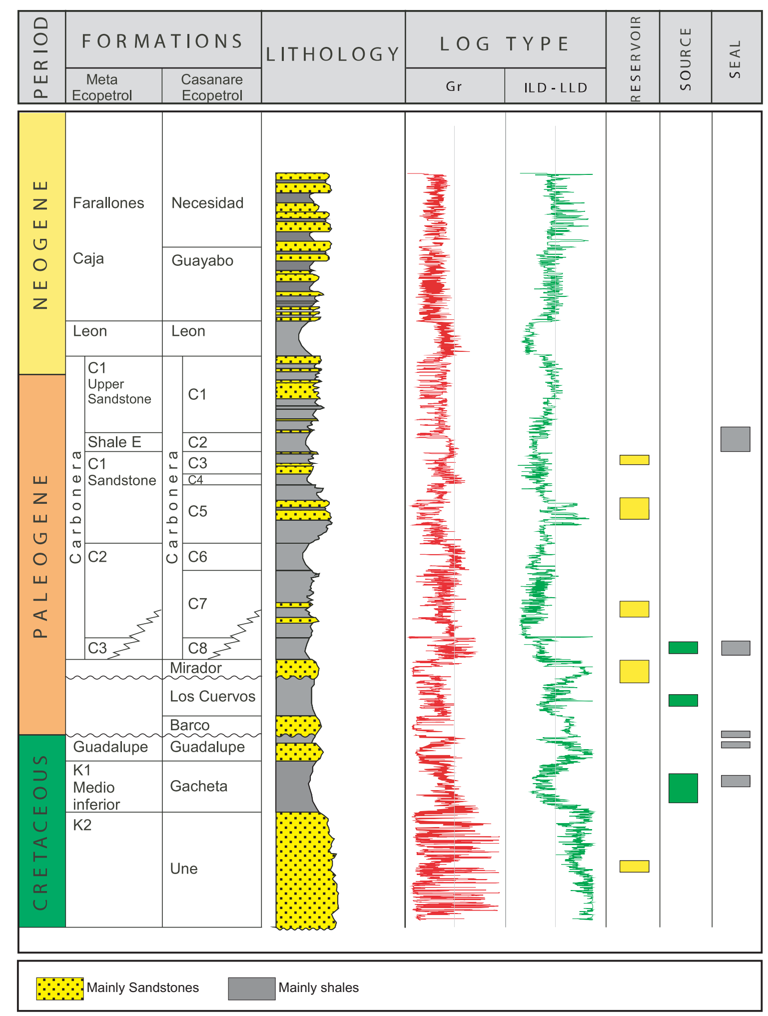
The source rock geochemical information interpreted for the Eastern Llanos Basin includes %TOC and Rock-Eval Pyrolysis data from 2402 samples taken in 129 wells; additionally 1326 organic petrography samples from 133 wells were interpreted.

Crude oil and extracts information from 620 bulk analysis samples, 705 liquid chromatography samples, 978 gas chromatography samples, 771 biomarker samples, 271 isotopes samples and 1767 surface geochemistry samples were also interpreted.

SCHEMATIC CROSS SECTION
EASTERN LLANOS BASIN

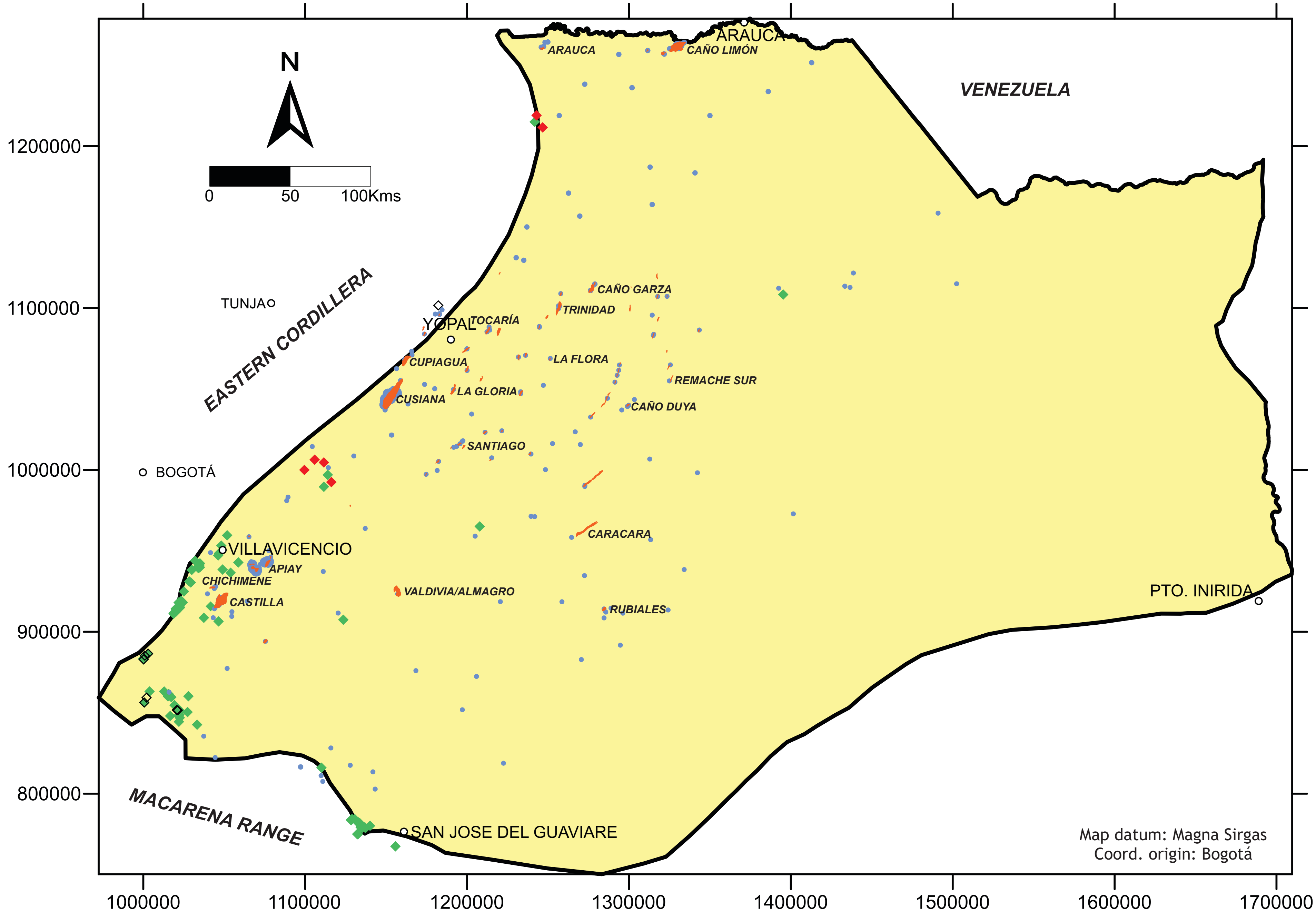


From Barrero et al., 2007



From Barrero et al., 2007

Wells and Seeps

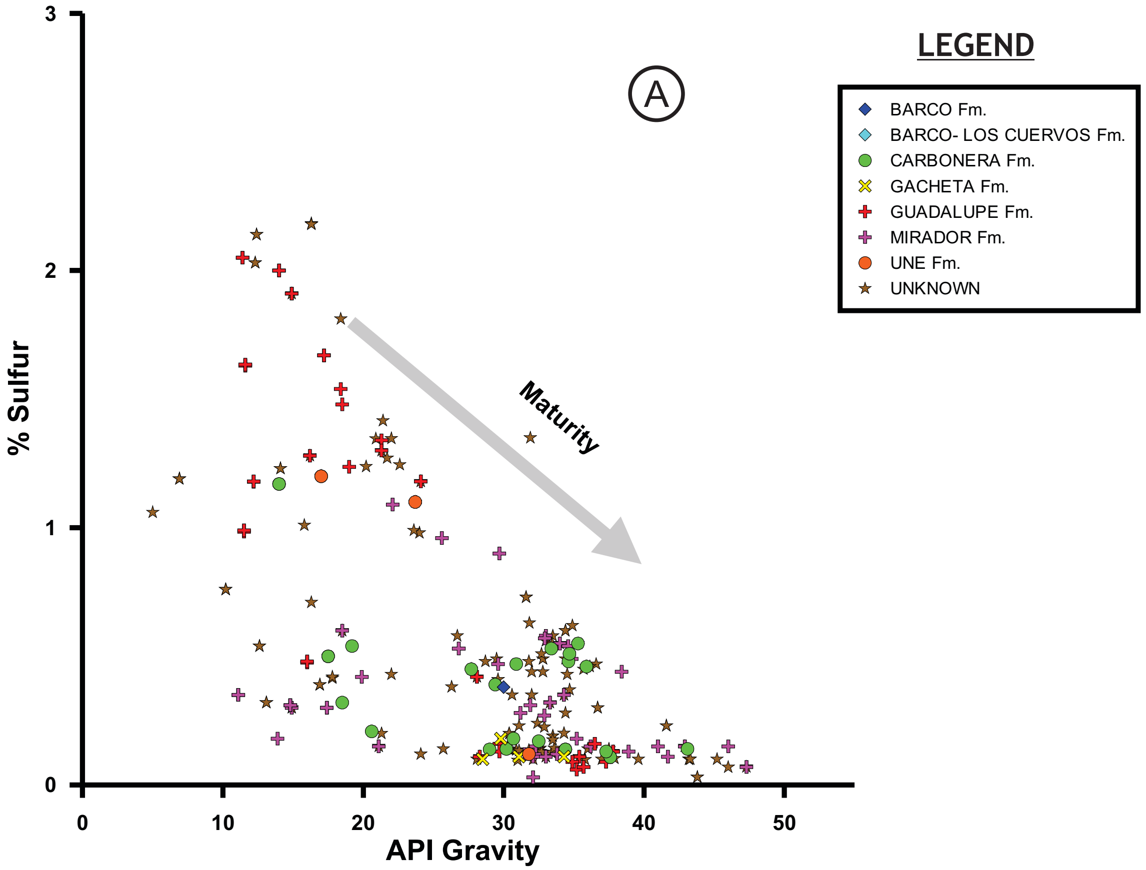


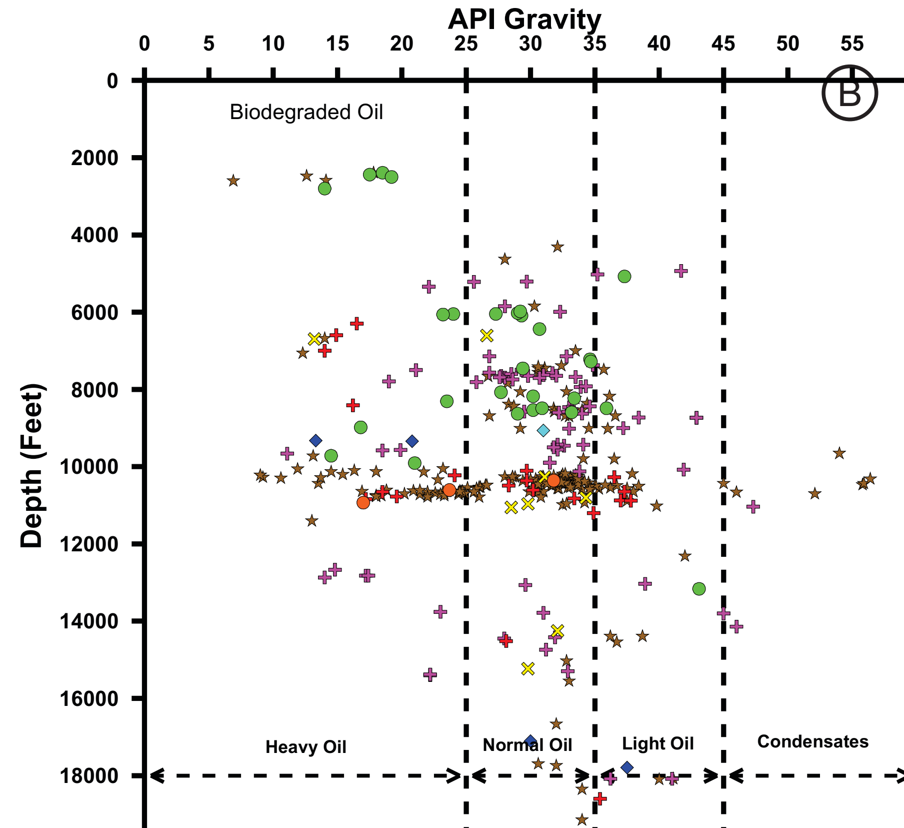
- Oil and gas fields
- Wells with geochemical information
- Oil seeps
- Gas seeps
- Undetermined seeps
- Cities/Towns

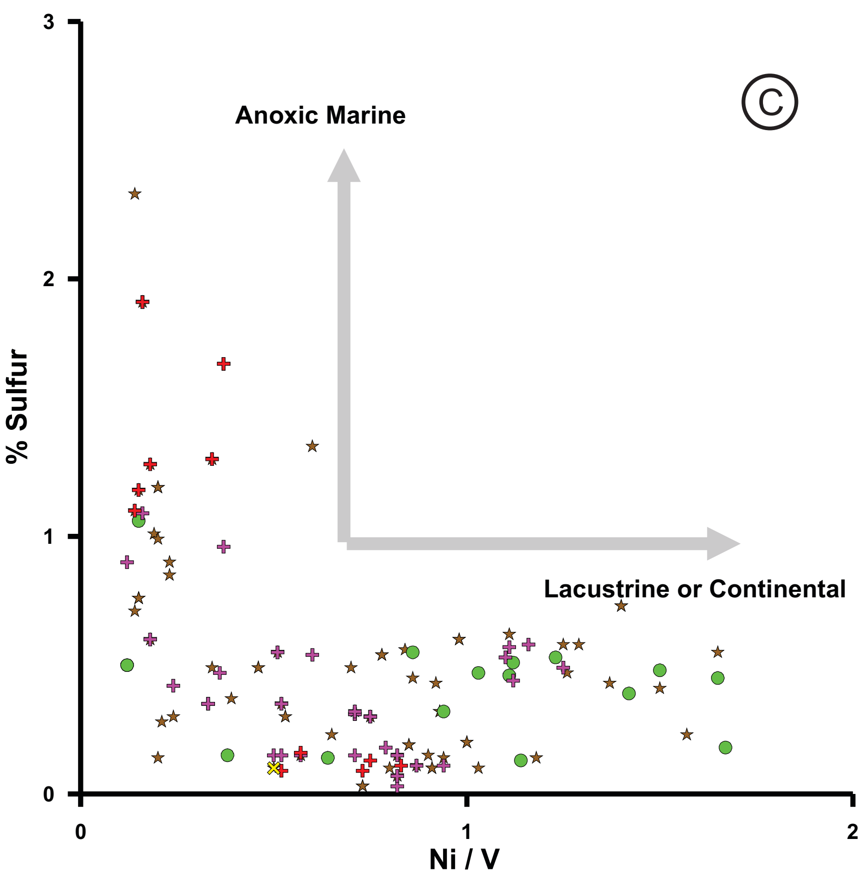
The number of wells and/or surface locations with geochemical information in the Eastern Llanos Basin is 301.

Oilseeps are located at the western and southern parts of the basin.

Crude Oil Quality





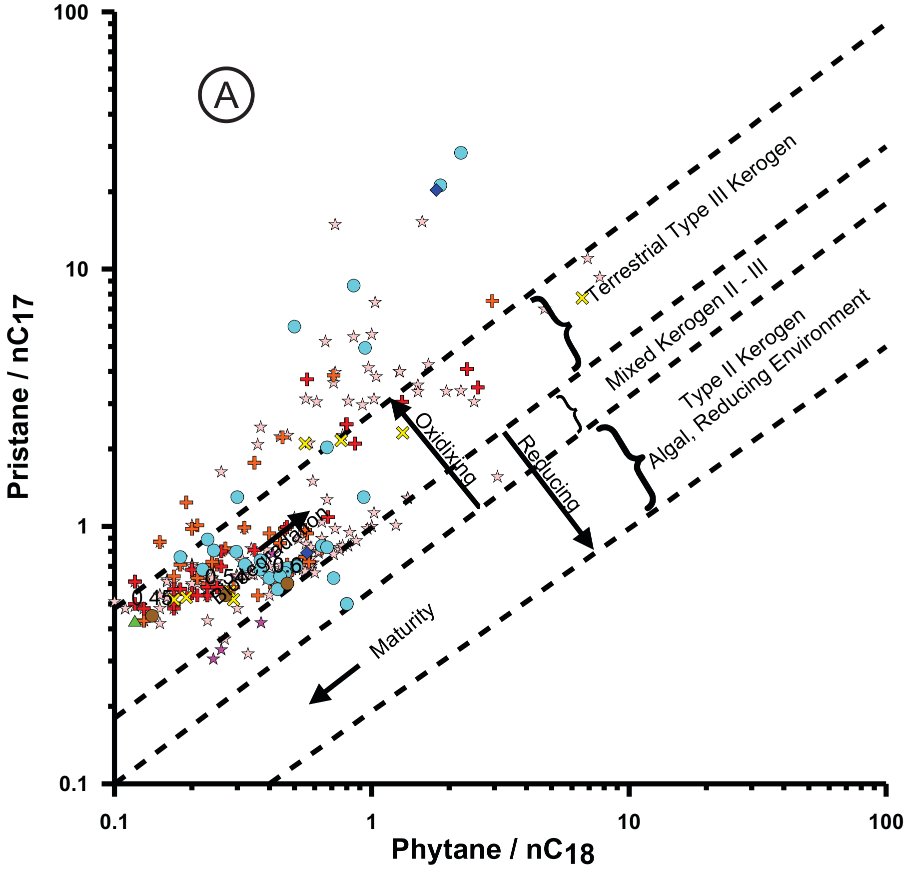


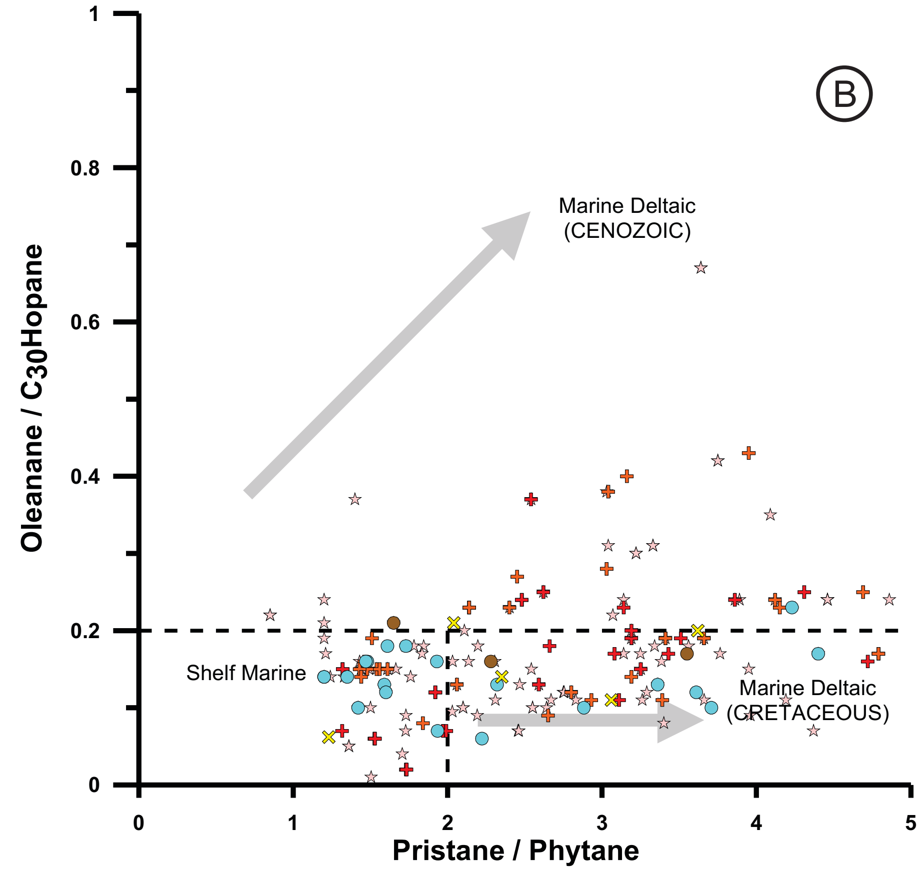
- Normal and light oils with API gravities ranging from 10° to 50° and sulfur content between 0 and 2.5% are present in the basin. There is no straight relationship between sulfur and API gravity, but oils above 25° API have sulfur values below 1%, and oils below 25° show sulfur content with values up to 3%. This suggests that in the basin there are oils with different thermal maturities and/or different degrees of preservation (biodegradation, water washing, etc.), because crudes having similar API gravities have different sulfur contents, which might indicate that biodegradation is increasing sulfur content and/or reducing API gravity, or different source rocks, considering that oils sourced from shales usually have lower sulfur content than oils from carbonates (Figure A).

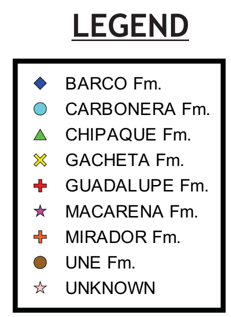
- There is no direct relationship between depth and crude oil quality, indicating that similar quality oils can be found at different stratigraphic levels, probably related to vertical migration along faults. But additionally there is the fact that different API gravity oils can be found at similar depths, reflecting different preservation (biodegradation) and/or thermal maturities (Figure B).

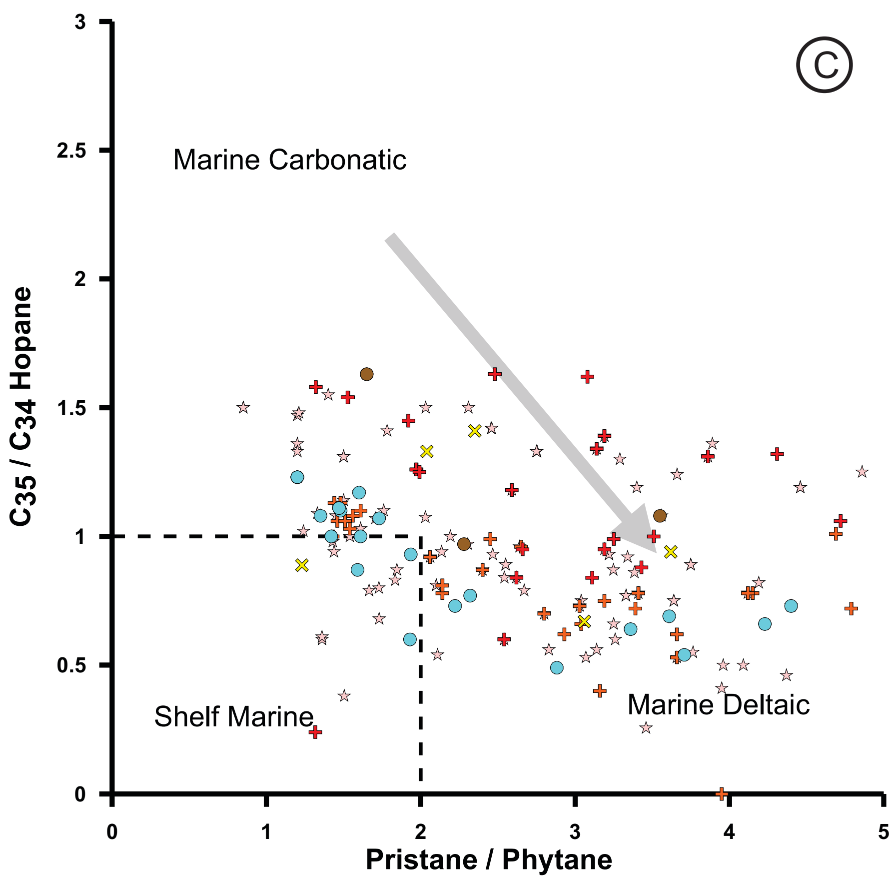
- The sulfur content of most crude oils is lower than 1%, and its Ni/V ratio below 1, suggesting that they are produced from rocks deposited in a marine suboxic environment with some terrigenous organic matter input (Figure C).

Depositional Environments







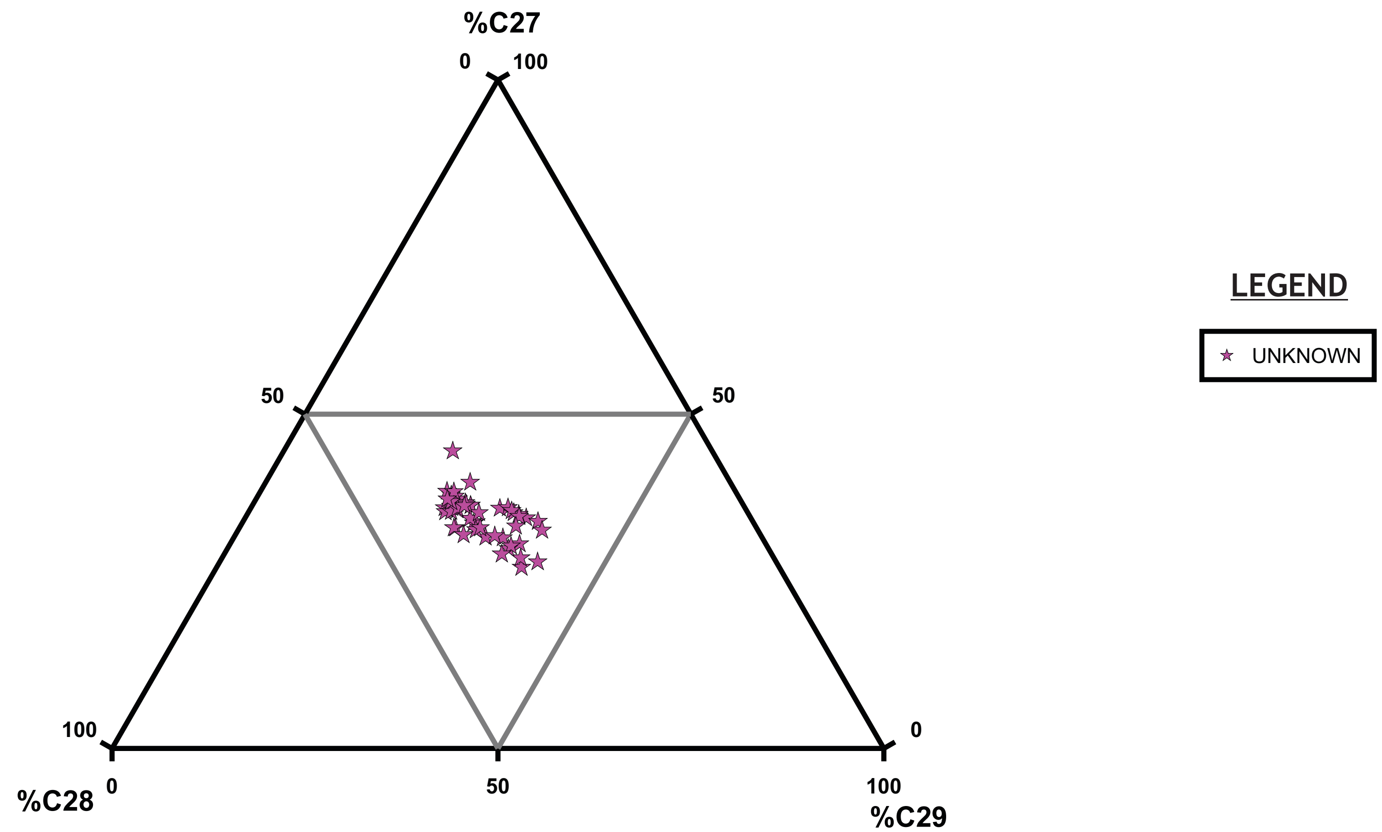


- The Phytane/nC18 vs Pristane/nC17 graph indicates that most of the oils have origin from terrestrial organic matter (Type III kerogen) deposited in an oxidizing environment, and have suffered low biodegradation. There are also some samples in the mixed kerogen range, suggesting a source with terrestrial and marine organic matter (Type II and III kerogens) deposited in more reducing conditions (Figure A).

- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that oils have low oleanane index values (<0.2) and Pr/Ph values ranging from 1 to 5, which indicates that these oils are generated from source rocks deposited in shelf marine to marine deltaic environments. There are some samples with higher oleanane index values (>0.2) and similar Pr/Ph values, indicating that these oils were generated from source rocks deposited in marine deltaic environments with important terrestrial organic matter input. The oleanane index has been also used as an age indicator of the source rock, with high oleanane values for oils generated in Cenozoic rocks and low oleanane values in oils from older rocks (Figure B).

- The Pristane/Phytane vs C35/C34 Hopane (Homohopane index) graph shows that oil samples have Pr/Ph values >1 and C35/C34 Hopane < 1, indicating that these oils were generated from siliciclastic rocks deposited in a shelf marine to deltaic environment. (Figure C).

Depositional Environments



- The steranes ternary plot shows predominance of C27 steranes over C29 steranes, which indicates that marine organic matter predominates in the source rocks.

- In summary, the crude oils in the basin correspond predominantly with generating facies deposited in siliciclastic environments ranging from marine to deltaic with an important terrestrial organic matter input. Some of these source rocks were deposited during the Cretaceous considering their low oleanane index values, but the higher Oleanane/C30 Hopane ratios (>0.2) along with high Pristane/Phytane ratios in some samples, suggest the possibility of Cenozoic generating facies deposited in deltaic marine environments.

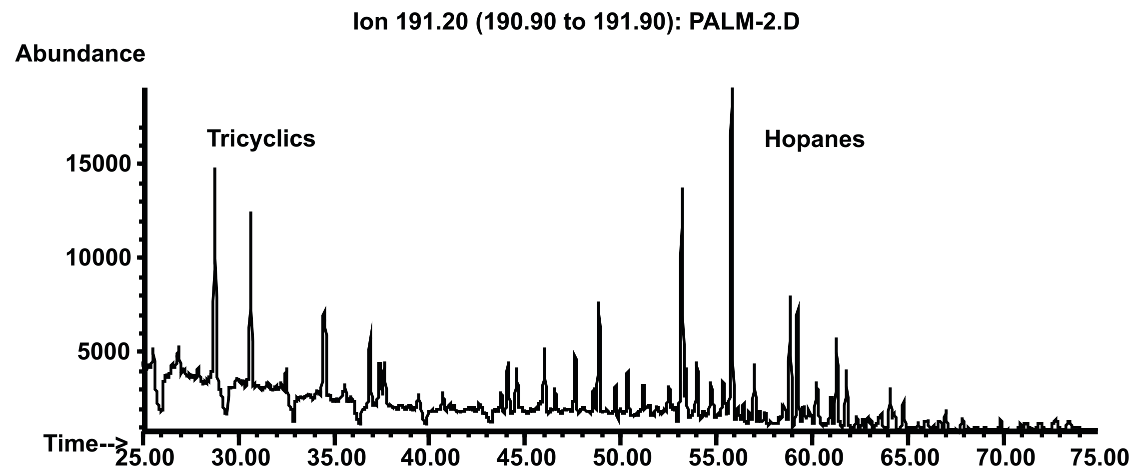
- These crude oils are of good quality with API gravities above 25° and sulfur content below 1% for most of them, and are well preserved (low biodegradation).

- At the Apiay sector the oils show mixing of carbonatic marine (C35/C34 > 1.0) and deltaic marine facies (Pristane/Phytane > 1.0).

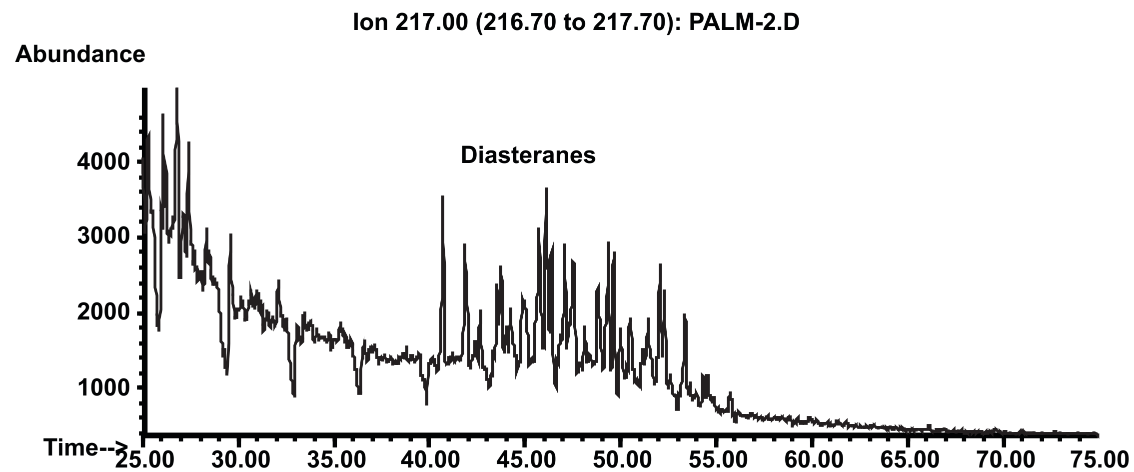
Chromatography

The Cusiana oil does not show biodegradation, has an abundant low molecular weight paraffins fraction and high diasteranes abundance, indicative of high thermal maturity.

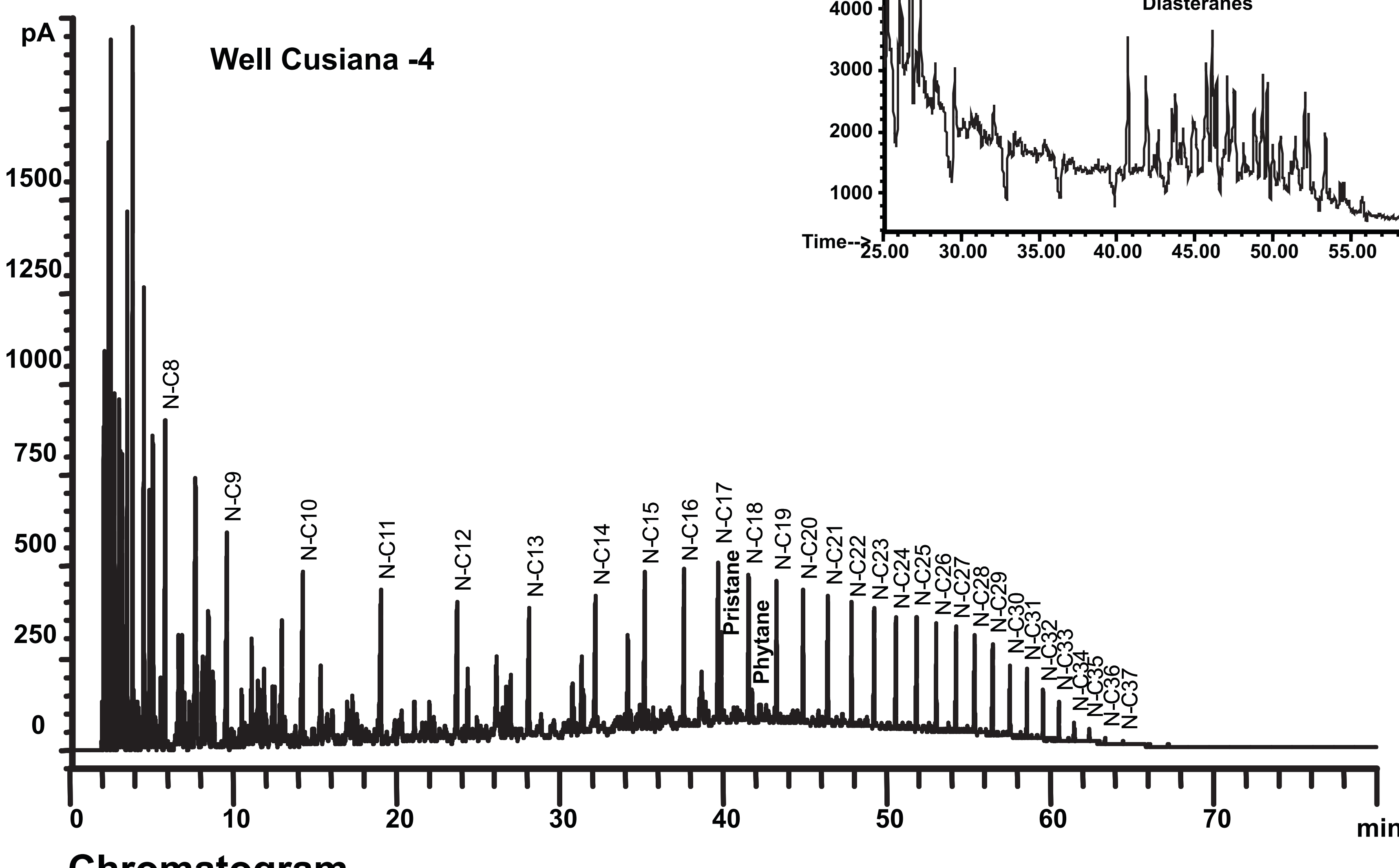
The Pristane/Phytane ratio > 1.0 and diasteranes abundance are indicative of generation from a siliciclastic (shale) source rock.



Fragmentogram m/z 191



Fragmentogram m/z 217



Chromatogram

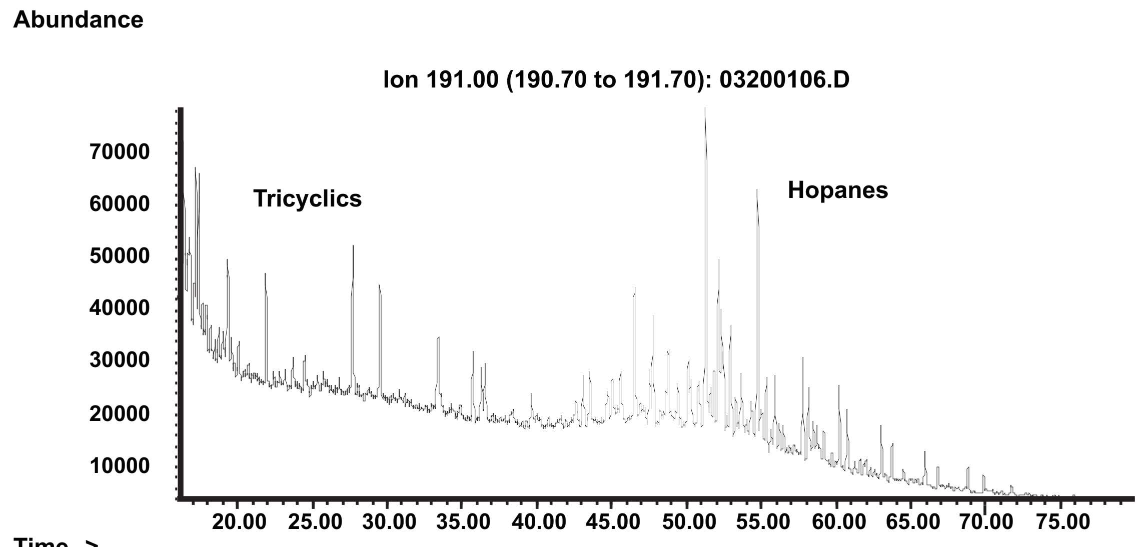
Chromatography

The oil of La Gloria-8 well is representative of an oil group typical of the central part of the basin, where biodegradation processes have been identified and most normal alkanes have been lost.

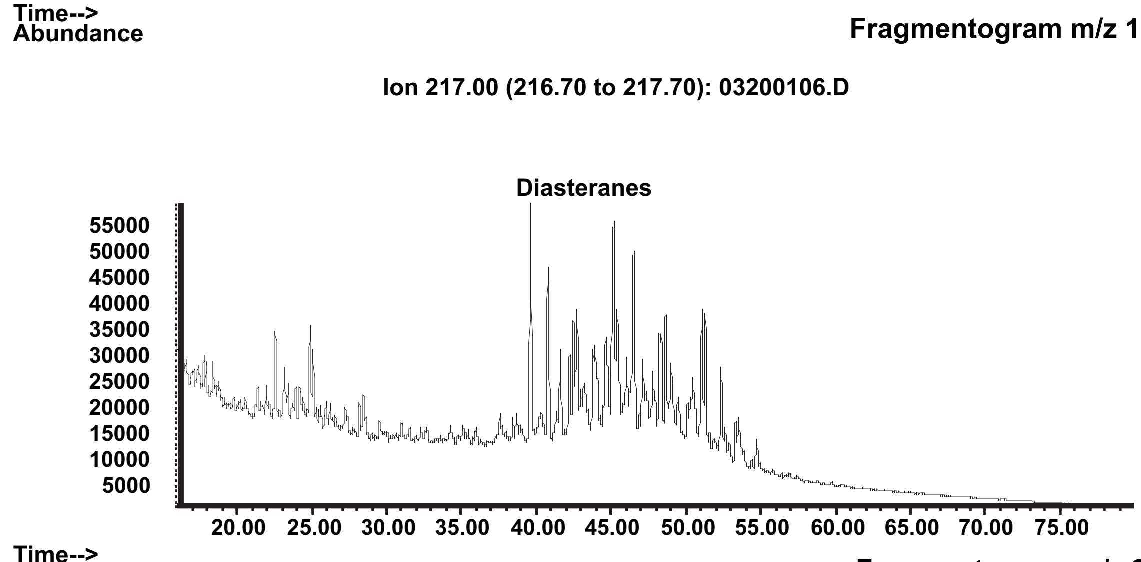
It is observed light oil refreshing from a second generation pulse that increases the API gravity.

Crude oil mixing is common in the central and southern parts of the basin.

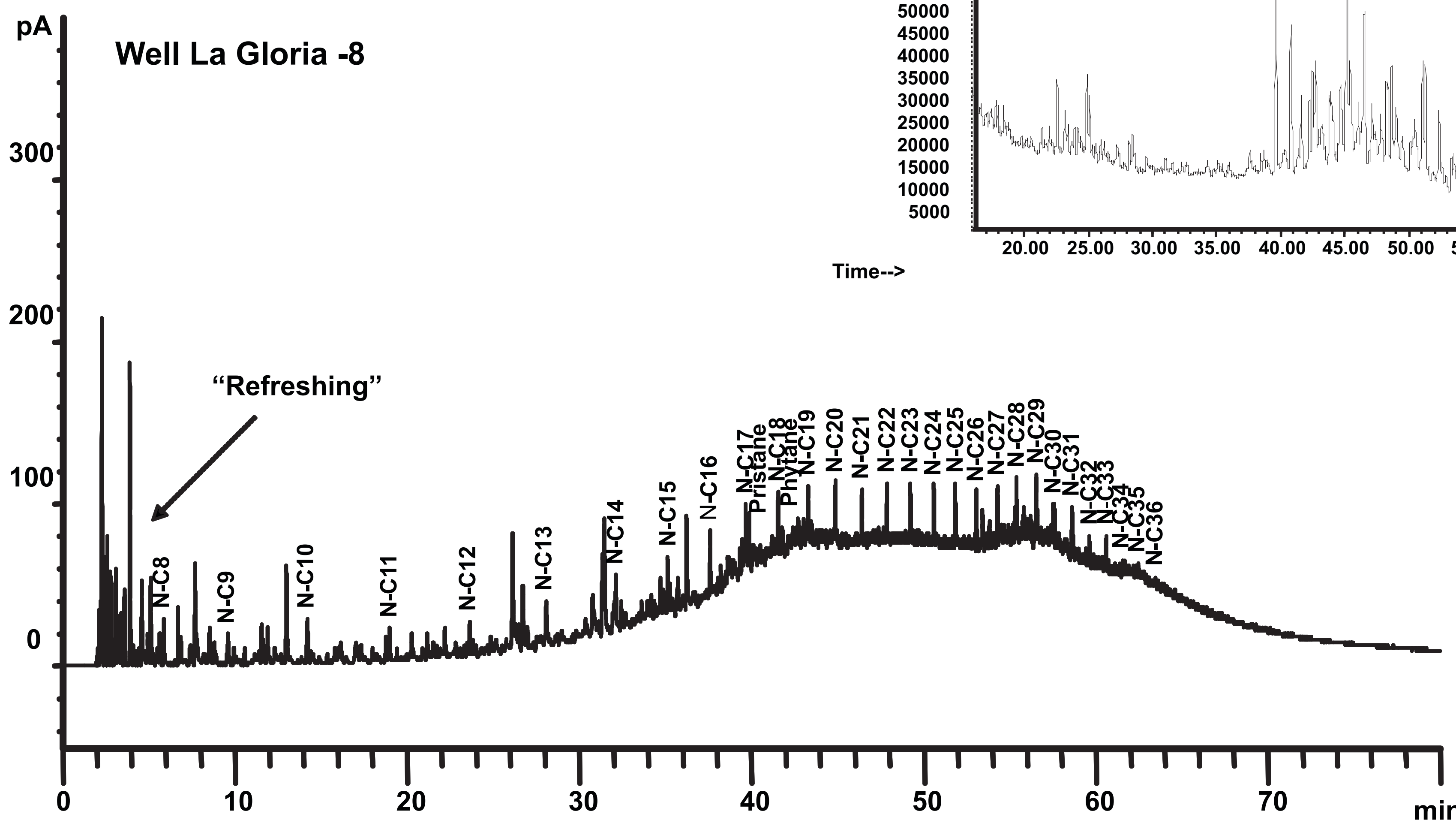
The diasteranes abundance suggests that the oil was generated from clay-rich rocks but also increased thermal maturity.



Fragmentogram m/z 191

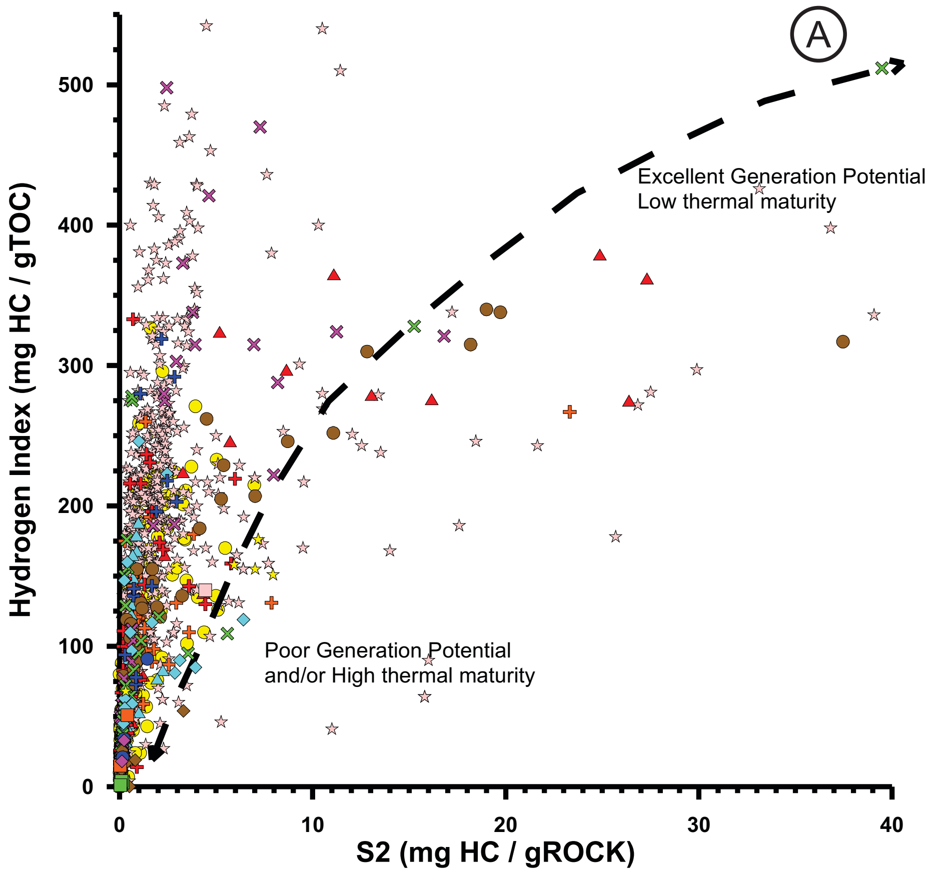


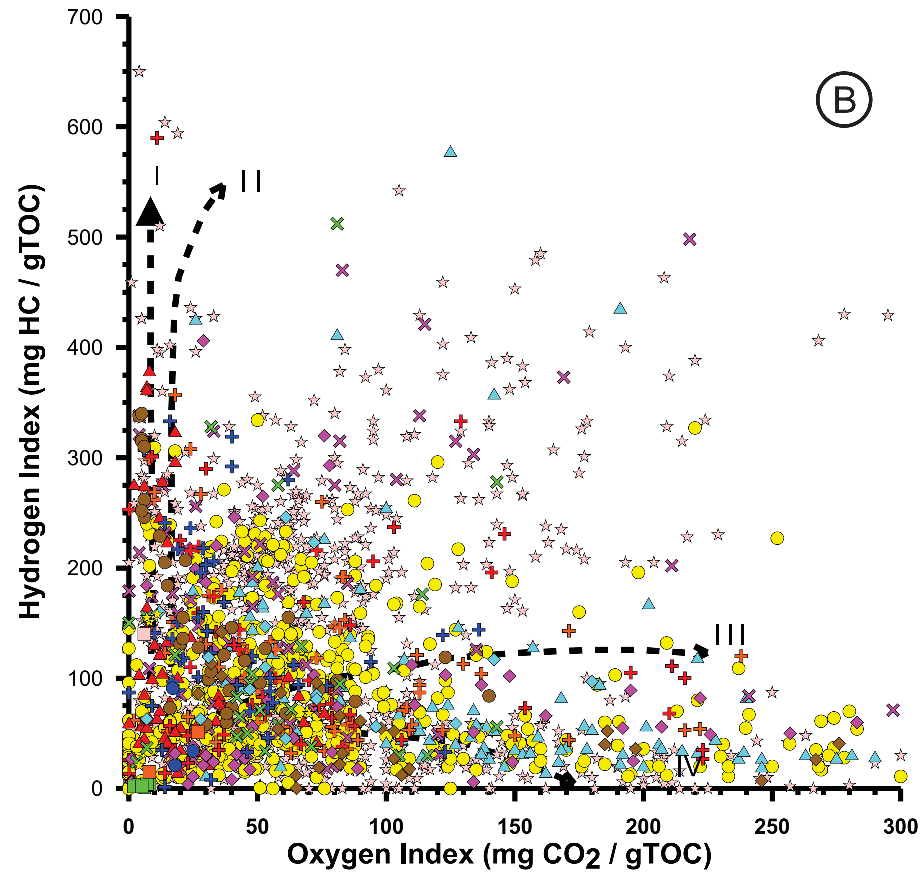
Fragmentogram m/z 217

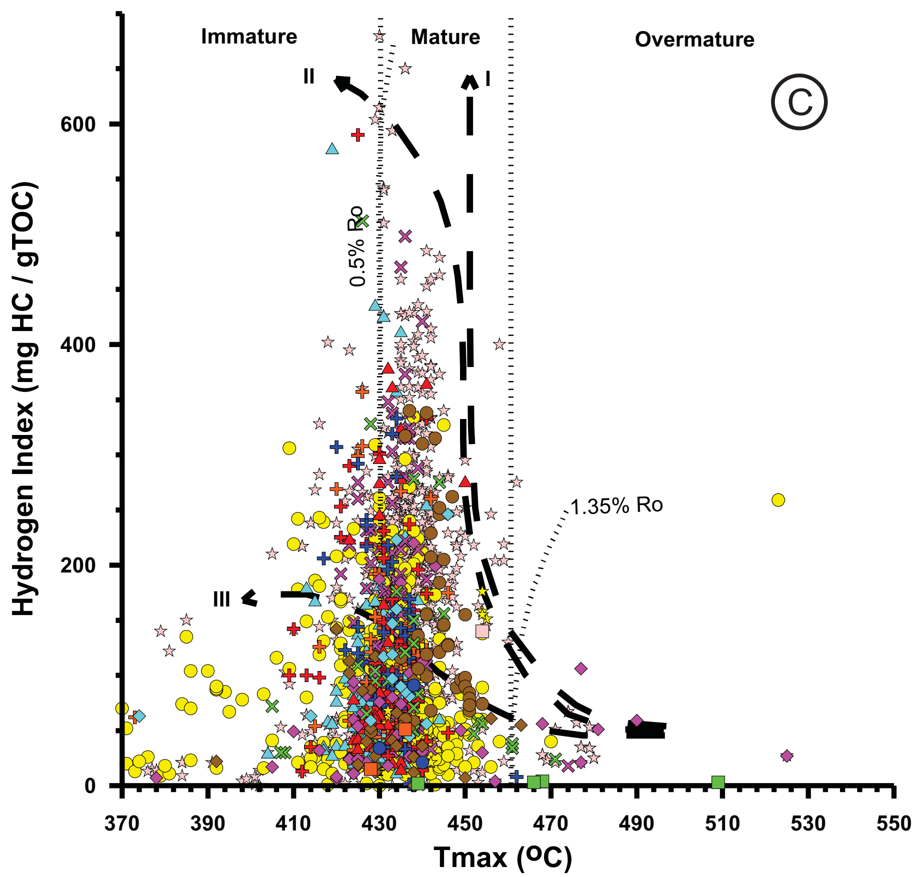


Chromatogram

Source Rock Characterization





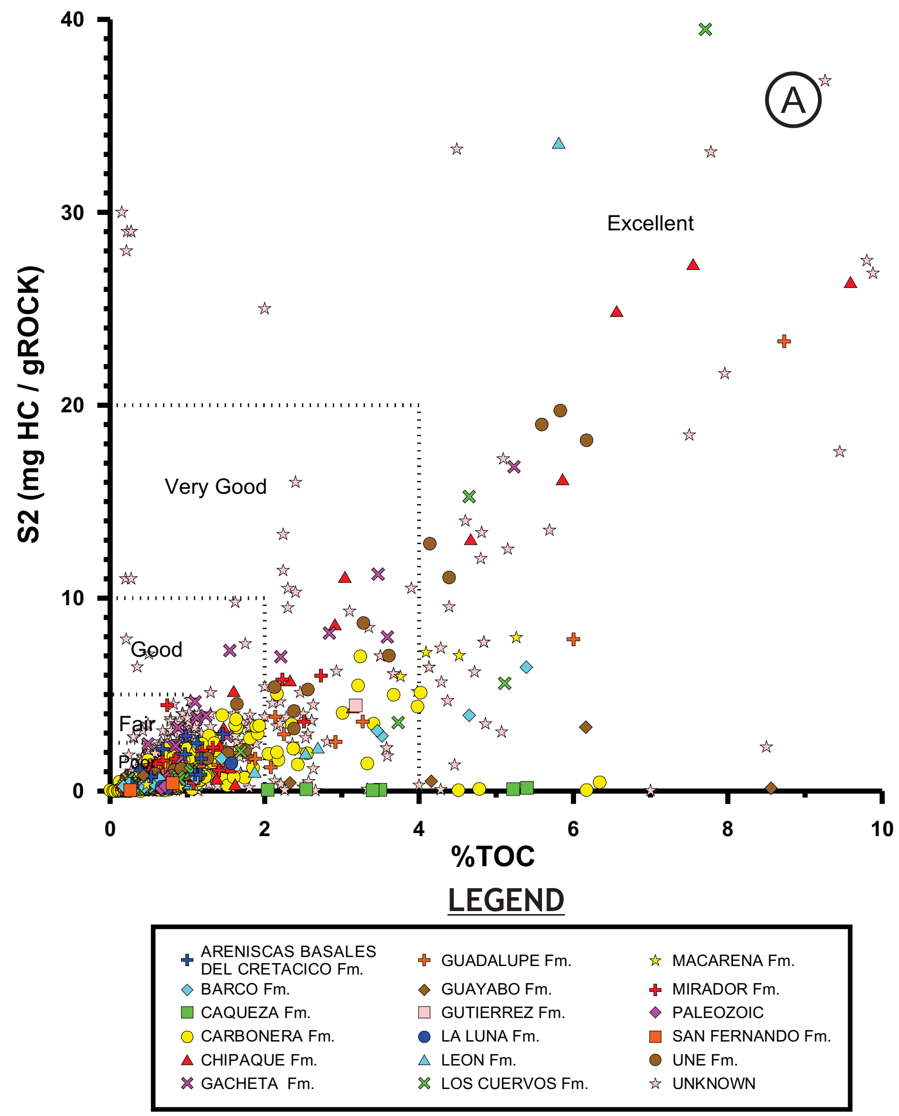


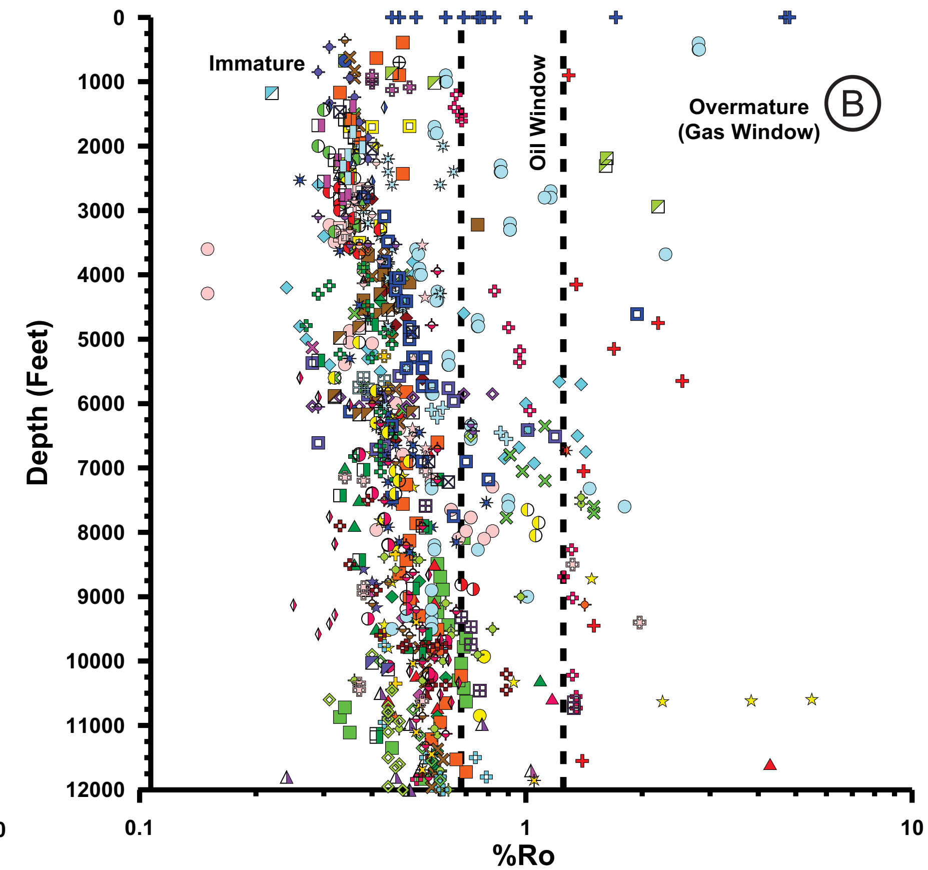
- The data obtained from pyrolysis of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Cretaceous Chipaque, Une and Gachetá formations and the Paleocene Los Cuervos Formation have good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock). (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cretaceous Chipaque, Une, Gachetá and Guadalupe formations along with samples from the Cenozoic Mirador, Los Cuervos and Carbonera formations and Paleozoic samples have type II-III oil-gas prone kerogen. Samples of the León Formation have type III-IV kerogen values (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples from the Cretaceous to Cenozoic units mentioned, have reached early to late oil generation conditions in the basin, with some samples of Paleozoic rocks overmature. The high thermal maturity reached by some samples explains the high API gravity of some oils found in the basin (Figure C). Additionally this high thermal maturity should explain the poor generation potential of many samples in the basin caused by kerogen depletion.

Source Rock Characterization





- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from Cretaceous units (Chipaque, Une and Gachetá formations) and Cenozoic units (Los Cuervos and Carbonera formations), with good to excellent oil generation potential (S2 up to 35 mg HC/g rock and % TOC up to 9). There are some samples of the Barco Formation with high %TOC but low S2 values (< 5 mg HC/g rock) suggesting that the kerogen in this unit has a low proportion of labile compounds and should not be a very good source for hydrocarbons in the basin.

-The vitrinite reflectance (%Ro) information shows that in the foreland wells the sedimentary sequence deposited in the basin is mostly immature, and is mature in those wells in or close to the foothills of the Eastern Cordillera at the western part of the basin (Figure B).

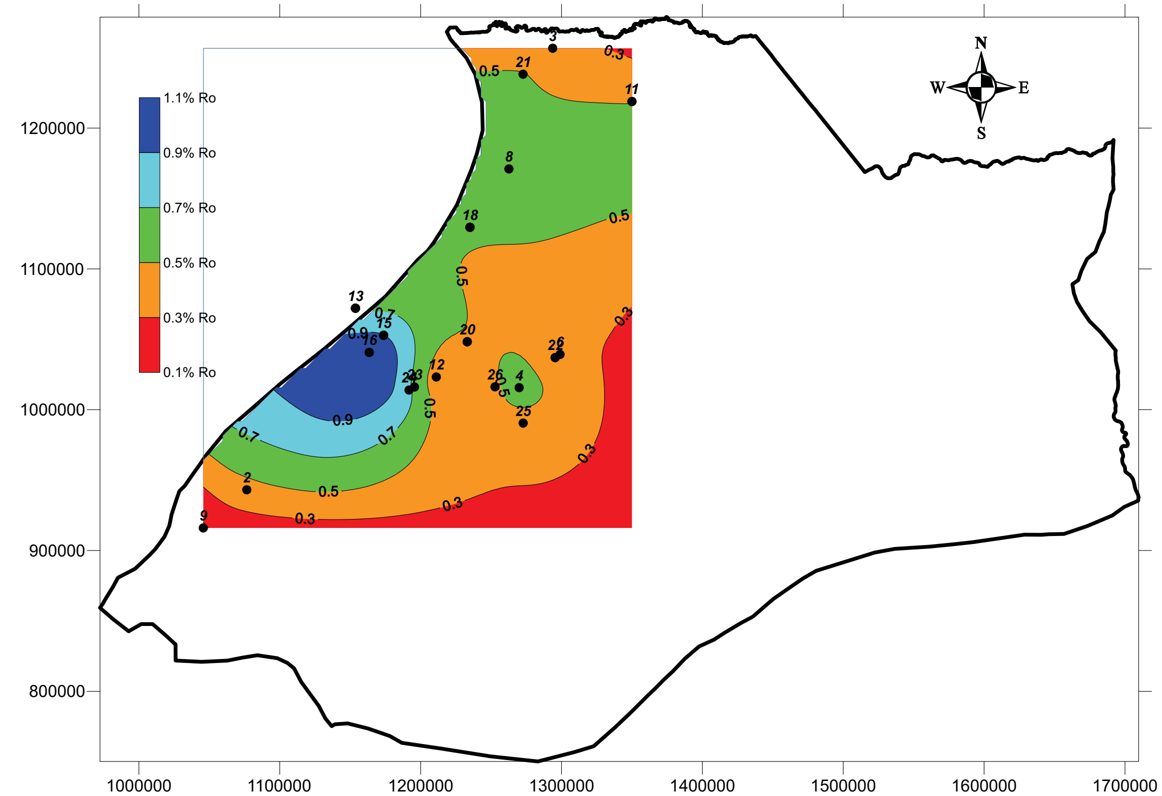
-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Cretaceous rocks of the Chipaque, Une and Gachetá formations and the Cenozoic rocks of the Los Cuervos and Carbonera formations have good to excellent generation potentials. Thermal maturity data (Tmax and %Ro) indicate that the rocks have reached different levels of maturity and thermal histories, that along with biodegradation explain the wide range of crude oil API gravities and oil mixing in the basin.

Source Rock Quality and Maturity Maps

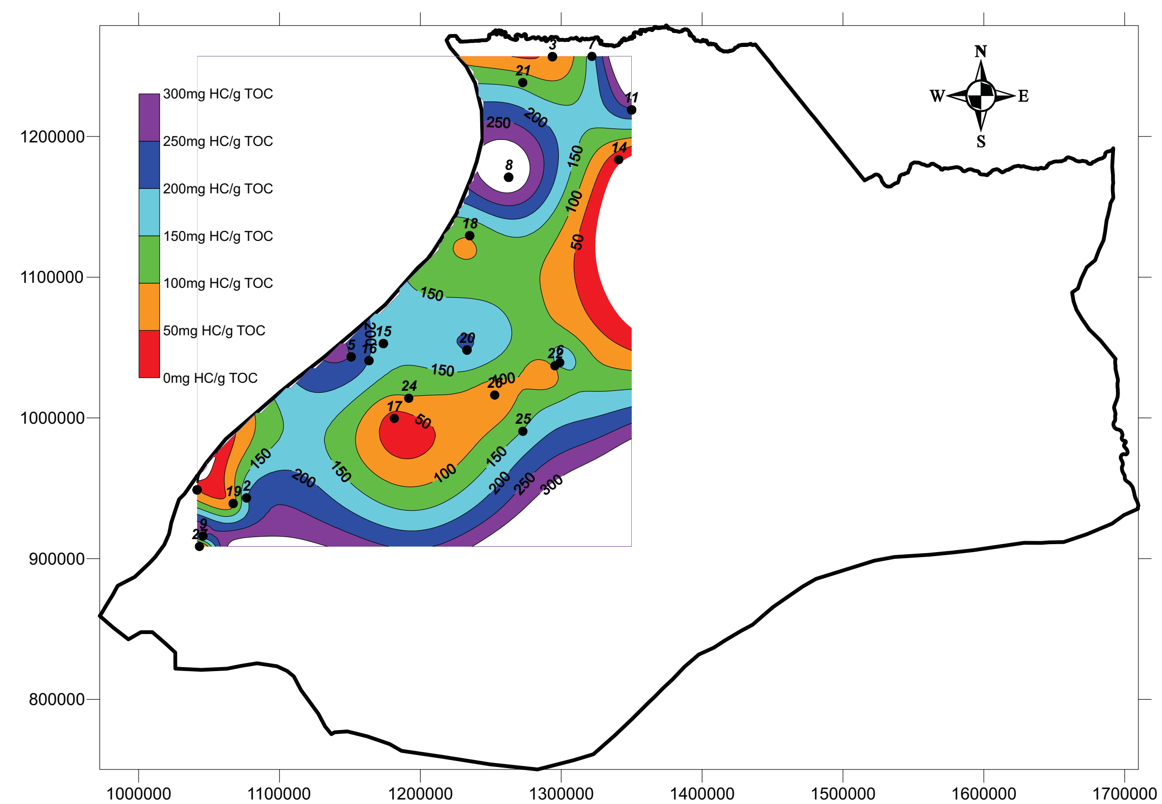
Gacheta Formation

LEGEND

1. ANACONDA-1
2. APIAY-4P
3. ARAUQUITA-1
4. ARIMENA-1
5. BUENOS AIRES X-14
6. CAÑO DUYA-1
7. CAÑO VERDE-1
8. CASANARE-1
9. CASTILLA-1
10. CHAPARRAL-1
11. CHIGUIRO-1
12. ENTRERRIOS-1
13. GOLCONDA A-1
14. LA HELIERA-1
15. LA MARÍA-1
16. LETICIA-1
17. POMARROSO-1
18. PORE-1
19. QUENANE-1
20. RANCHO HERMOSO-1
21. RÍO ELE-1
22. SAN JOAQUÍN-1
23. SANTIAGO-1
24. SANTIAGO-2
25. SIMÓN-1
26. SURIMENA-1
27. YALÍ-1



Vitrinite reflectance (%Ro)

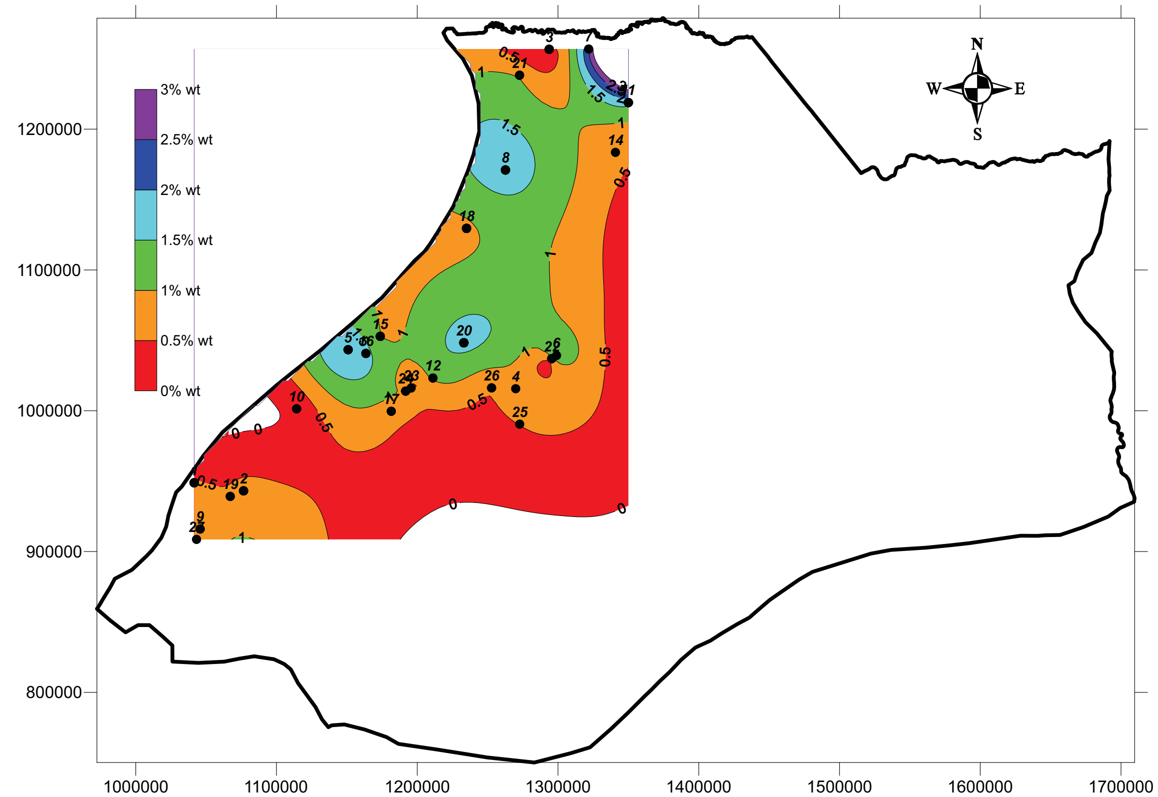


Hydrogen Index

Map datum: Magna Sirgas
Coord. origin: Bogotá

Source Rock Quality and Maturity Maps

Gacheta Formation



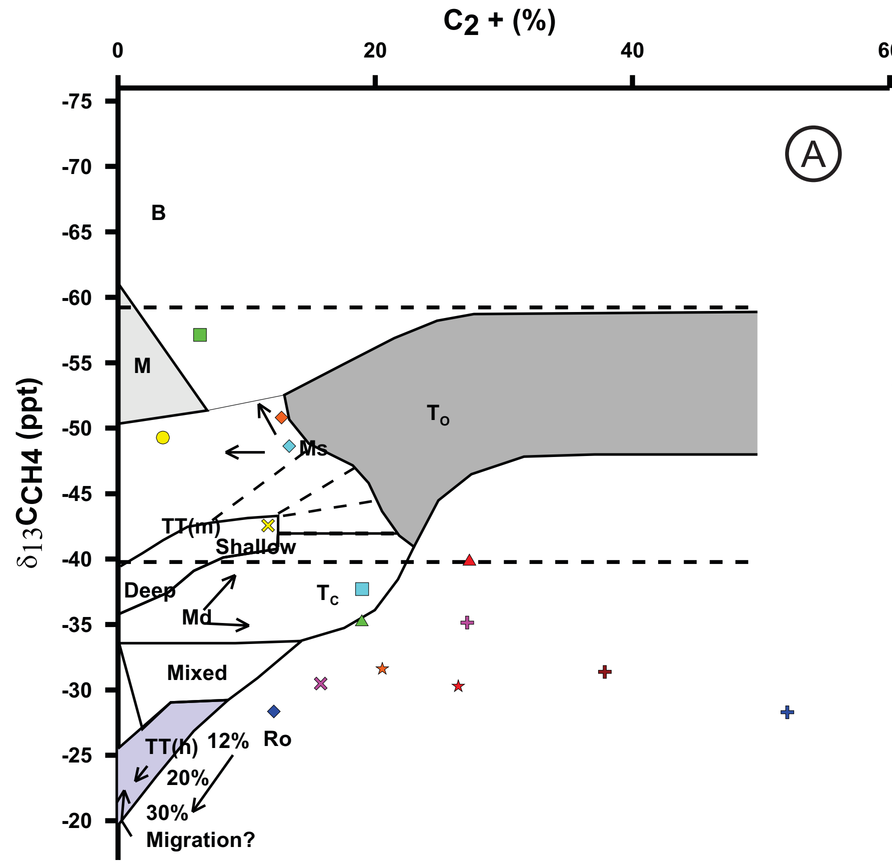
LEGEND

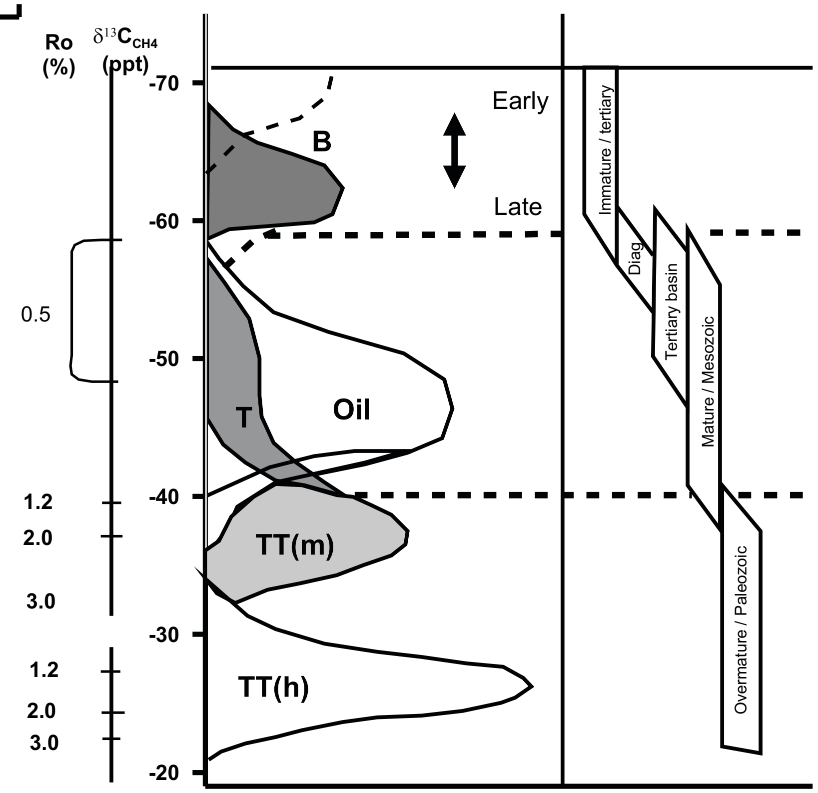
1. ANACONDA-1
2. APIAY-4P
3. ARAUQUITA-1
4. ARIMENA-1
5. BUENOS AIRES X-14
6. CAÑO DUYA-1
7. CAÑO VERDE-1
8. CASANARE-1
9. CASTILLA-1
10. CHAPARRAL-1
11. CHIGUIRO-1
12. ENTRERRIOS-1
13. GOLCONDA A-1
14. LA HELIERA-1
15. LA MARÍA-1
16. LETICIA-1
17. POMARROSO-1
18. PORE-1
19. QUENANE-1
20. RANCHO HERMOSO-1
21. RÍO ELE-1
22. SAN JOAQUÍN-1
23. SANTIAGO-1
24. SANTIAGO-2
25. SIMÓN-1
26. SURIMENA-1
27. YALÍ-1

Organic Matter Content (TOC)

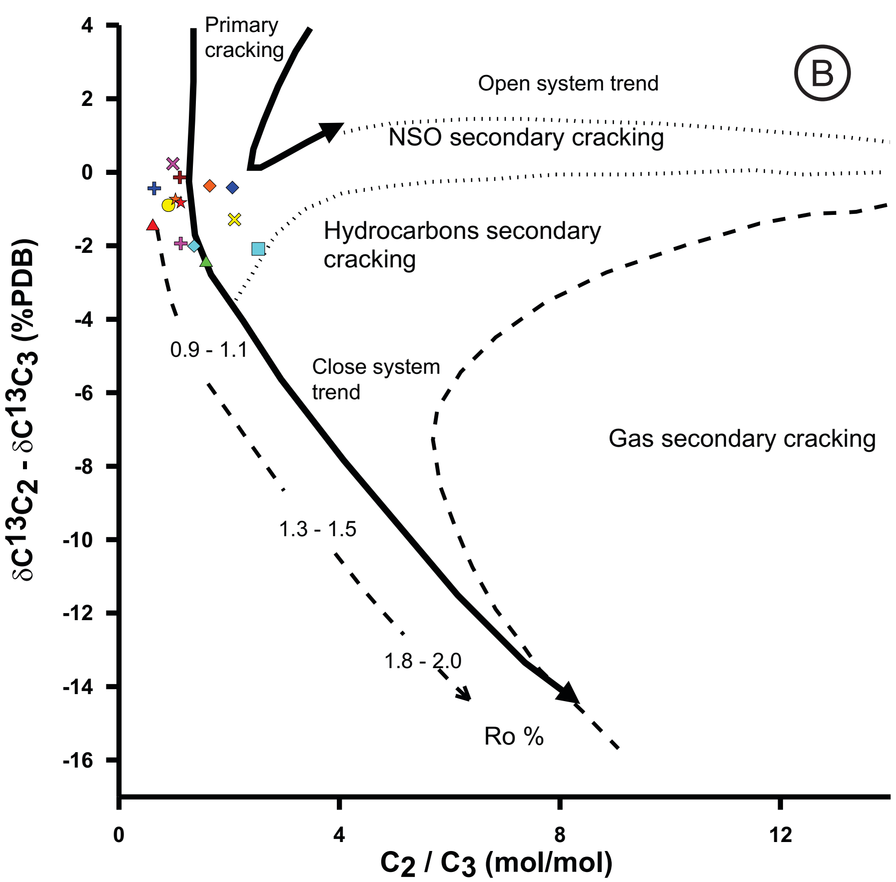
Map datum: Magna Sirgas
Coord. origin: Bogotá

Gas Characterization





B	Biogenic gas
T	Crude oil gases
To/Tc	Crude and condensate gases
TT(m)	Dry gases associated to sapropelic organic matter.
TT(h)	Gases associated to humic organic matter
M	Mixed gases
Md	Deep Migration
Ms	Shallow Migration

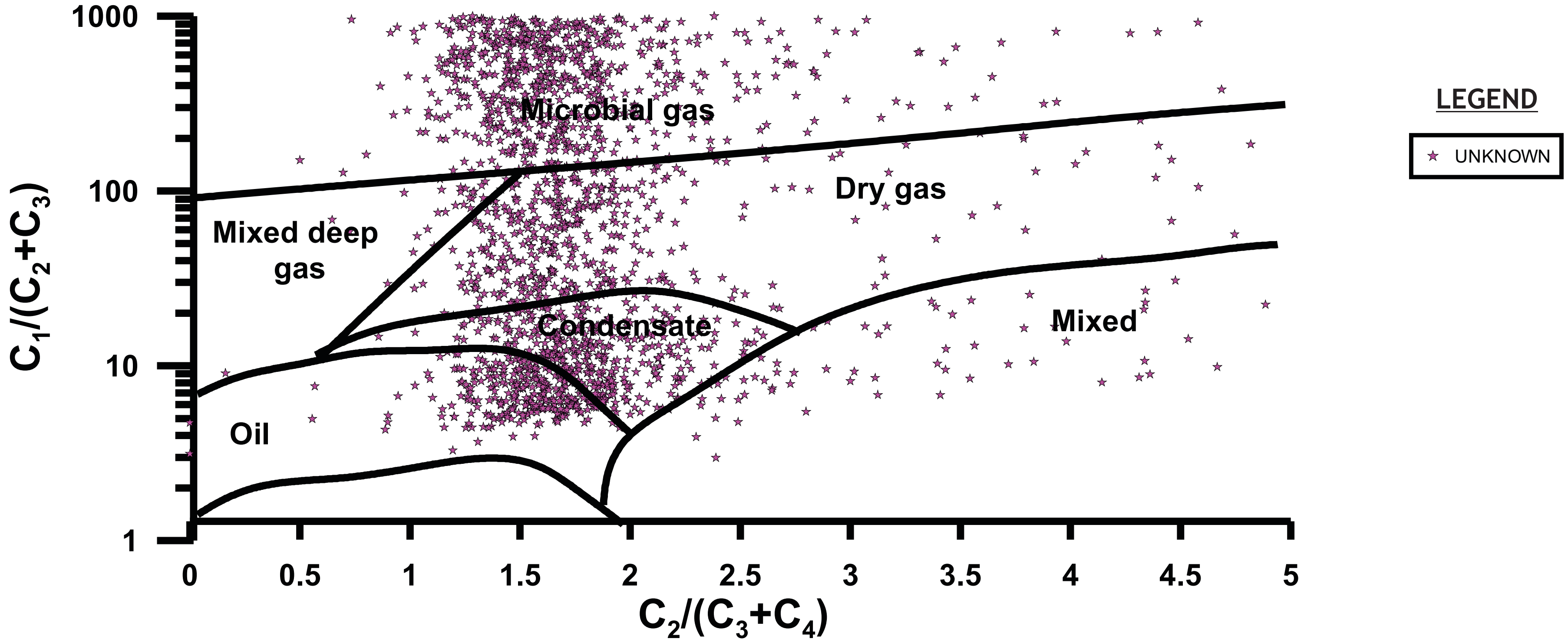


- The samples taken in the Eastern Llanos basin correspond to crude oil gases.

- The C2+(%) vs d13C Ch4 (ppm) diagram (Schoell, 1983), suggests that the gas samples correspond to a variety of processess like mixing, differential thermal maturity and biodegradation (Figure A).

- The C2/C3 vs d13C C2 - d13C C3 diagram, suggest that the gas samples analized were originated by primary cracking (Figure B).

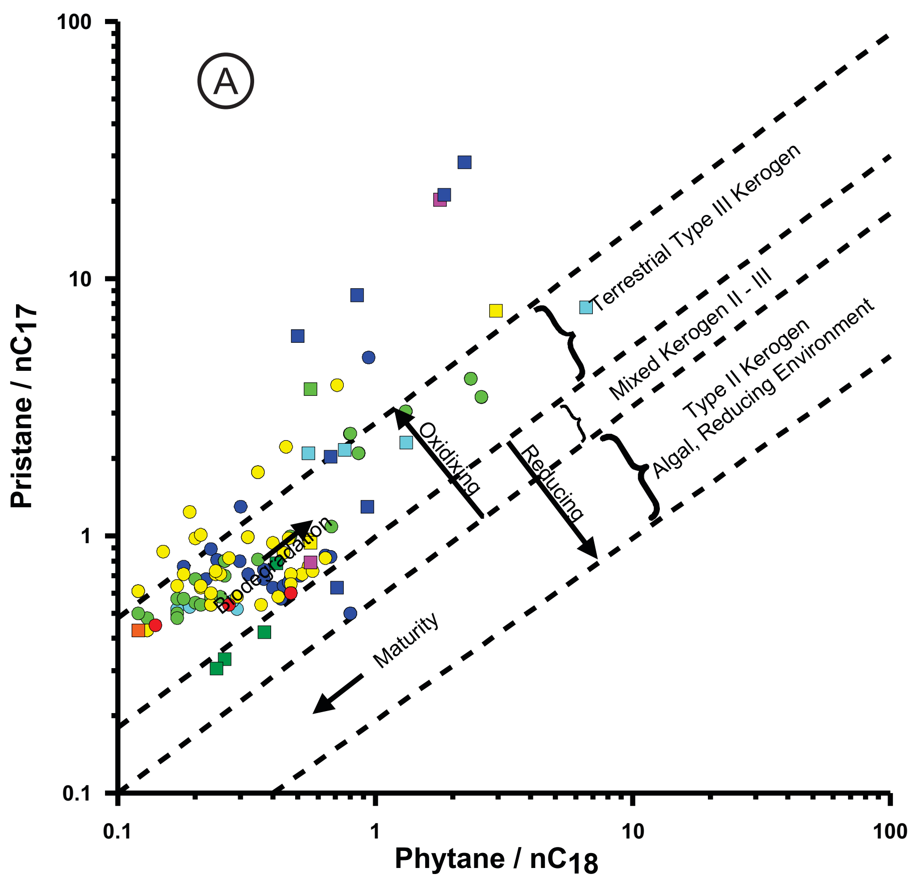
Surface Geochemistry

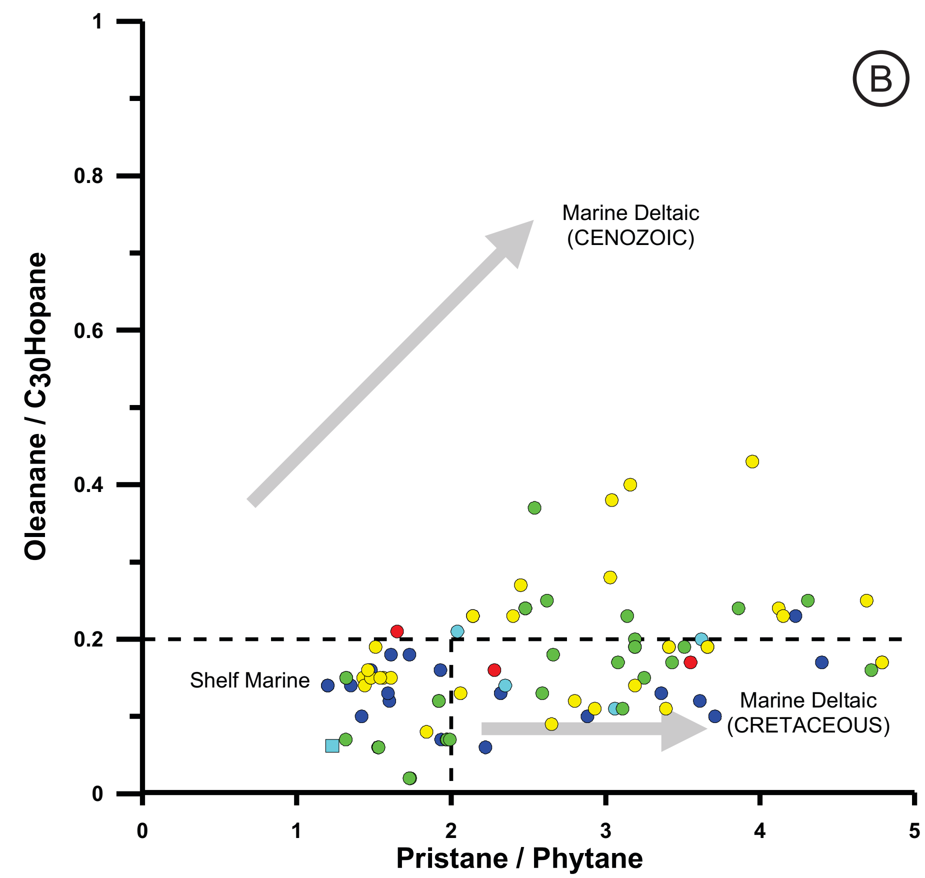


Compositional data from surface geochemistry samples indicate that there are hydrocarbons of thermogenic and biogenic origin at the basin, formed mainly during oil and gas generation window indicative of a variable maturity level of the sources at the basin.

The microbial gas found in the basin, characterized by its very high content of methane, could be related to bacterial degradation, considering the fact that it has similar C2/(C3+C4)ratios regarding thermogenic gases.

Petroleum Systems (Crude-Rock Correlations)





LEGEND

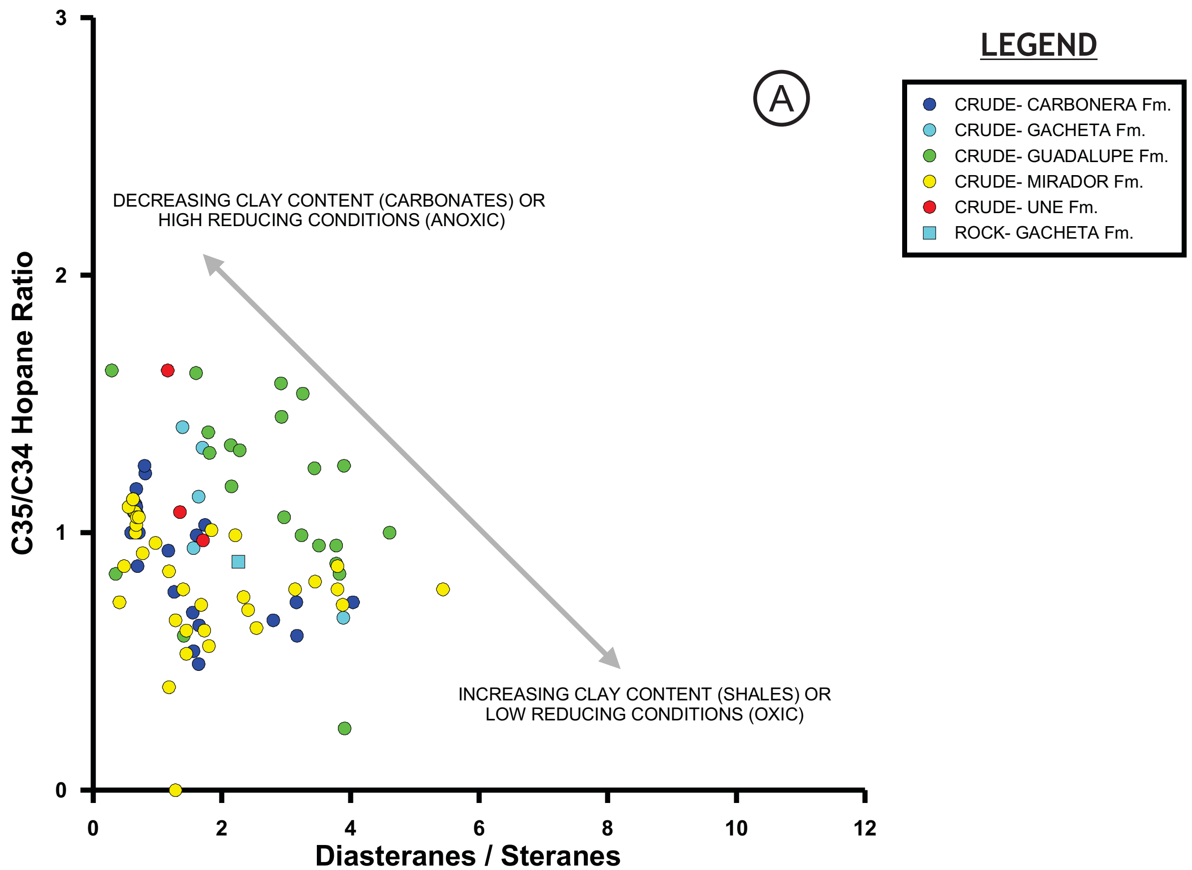
- CRUDE- CARBONERA Fm.
- CRUDE- GACHETA Fm.
- CRUDE- GUADALUPE Fm.
- CRUDE- MIRADOR Fm.
- CRUDE- UNE Fm.
- ROCK- BARCO Fm.
- ROCK- CARBONERA Fm.
- ROCK- CHIPAQUE Fm.
- ROCK- GACHETA Fm.
- ROCK- GUADALUPE Fm.
- ROCK- MACARENA Fm.
- ROCK- MIRADOR Fm.

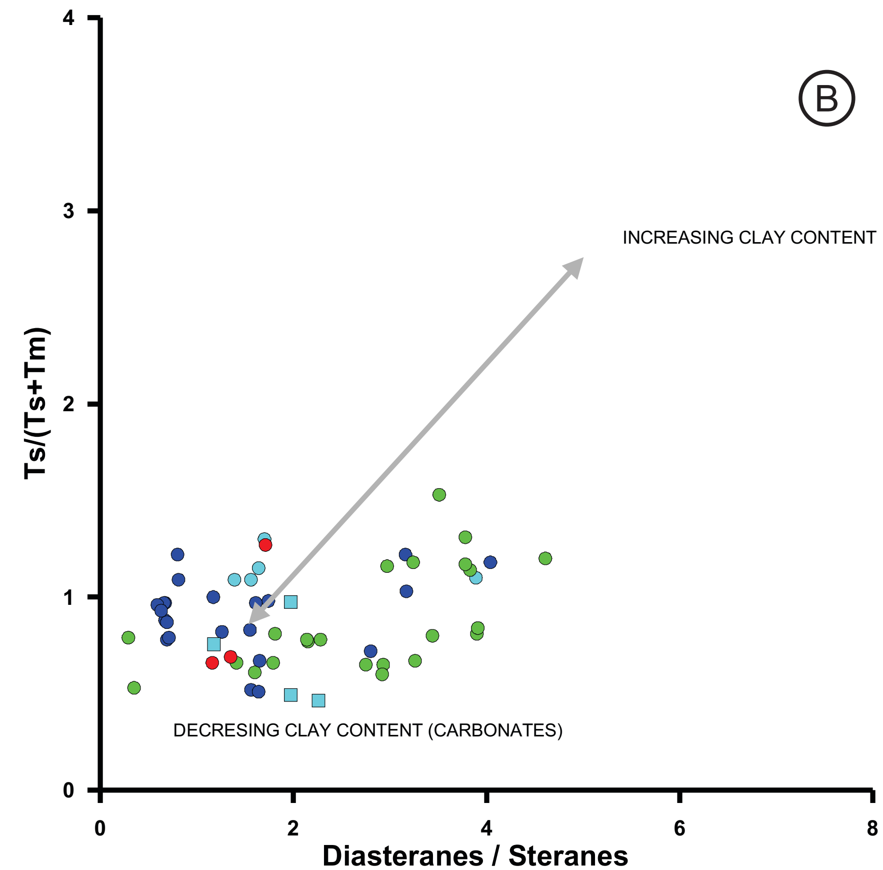
- There are very few extract samples in the basin to provide strong correlations with the oils found in the basin, but the few extracts from the Gachetá Formation show some correlation with crude oils from the Une, Guadalupe, Mirador and Carbonera reservoirs (Figure A).

- This indicates that the Gachetá Formation could be the main source for the accumulations found in the basin. However the presence of oils with Oleanane/C30 Hopane > 0.2 is indicative of an alternate source in the basin of Tertiary age and/or with an important terrestrial organic matter input (Figure B).

-The oils with Oleanane/C30 Hopane > 0.2 are found in Upper Cretaceous (Guadalupe Fm.) and Tertiary reservoirs (Mirador and Carbonera formations), which are interbedded or in close proximity to Tertiary shale sequences deposited in transitional marine environments, which might have high terrestrial organic matter input, causing the increase of Oleanane/C30 Hopane ratios in these oils (Figure B).

Petroleum Systems (Crude-Rock Correlations)





- The C35/C34 Hopanes, Ts/(Ts+Tm) and diasteranes/steranes indicate that the rock extracts correspond to poor-clay rocks deposited under suboxic conditions (Figures A and B).

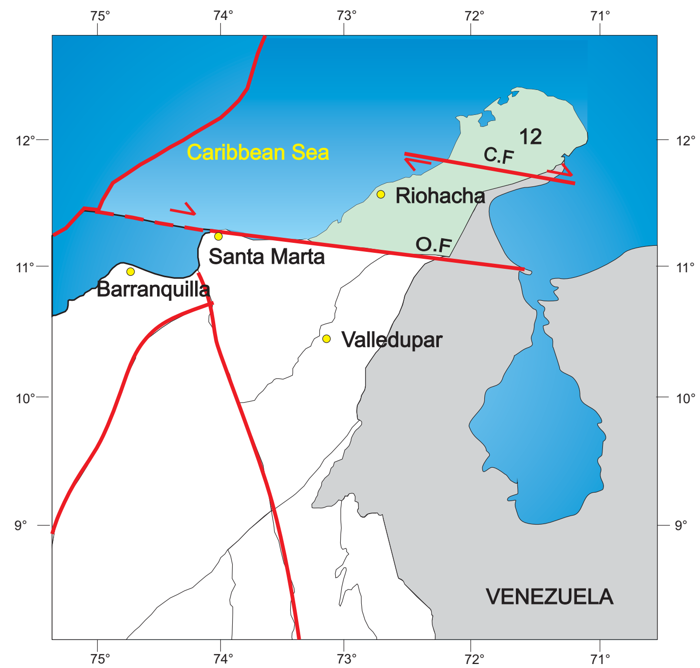
- Based on the crude-rock correlations and the geochemical evidence available for the basin, the following active petroleum systems for the basin could be proposed: Gachetá - Une (!), Gachetá - Guadalupe (!), Gachetá - Mirador (!), Gachetá - Carbonera (!), Los Cuervos - Guadalupe (.), Los Cuervos - Mirador (.) and Los Cuervos - Carbonera (.).

GUAJIRA BASIN

Generalities
Wells and Seeps
Source Rock Characterization
Gas Characterization
Surface Geochemistry

Generalities

GUAJIRA BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

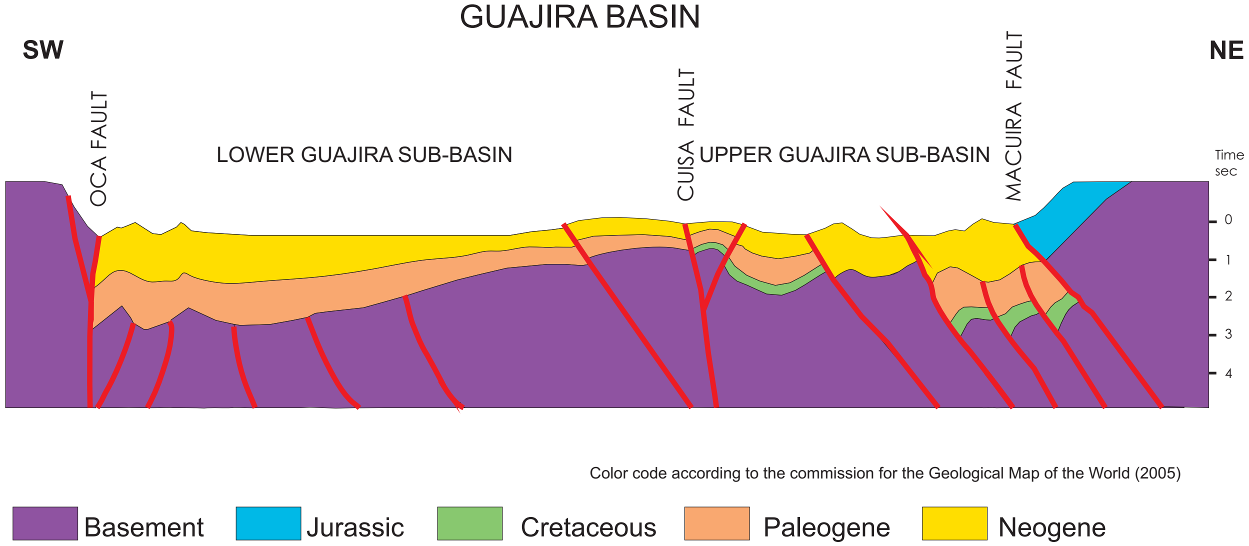
North and Northwest: Caribbean shoreline
Northeast: Caribbean shoreline
Southeast: Colombia-Venezuela border
South: Oca Fault (O.F.)

From Barrero et al., 2007

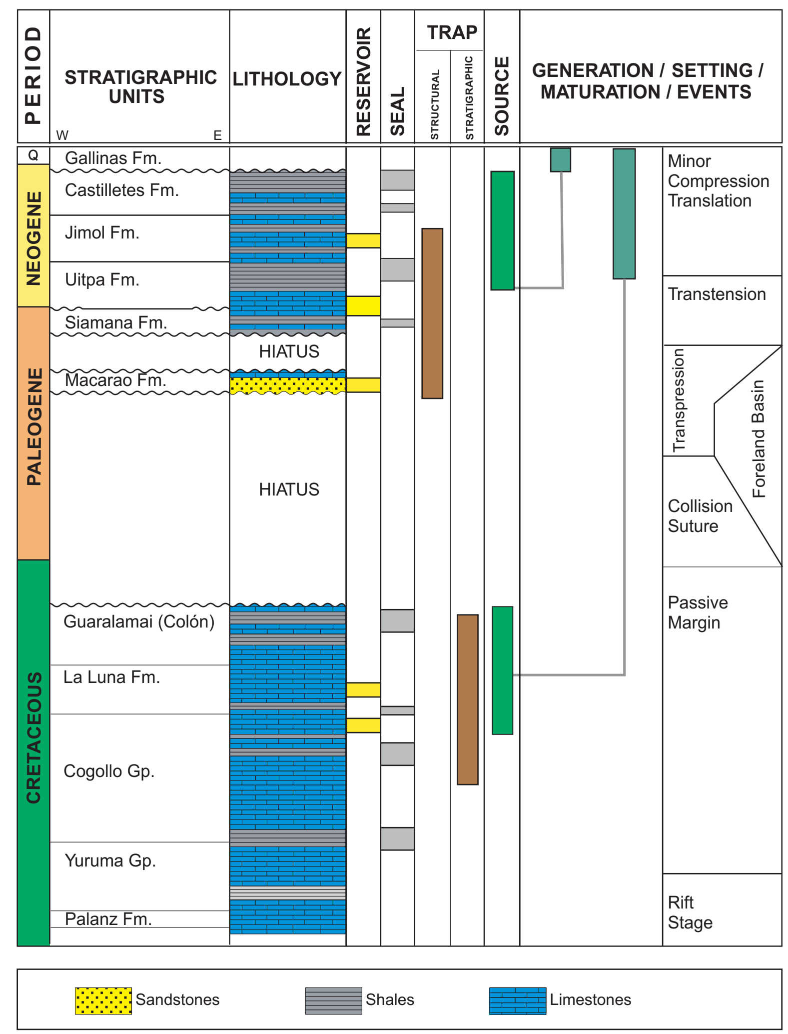
The source rock geochemical information interpreted for the Guajira Basin includes %TOC data from 10 samples taken in 2 wells; additionally 62 organic petrography samples from 3 wells and 361 surface geochemistry samples were interpreted.

Due to the lack of crude oil geochemical data, crude oil interpretation was not made for the basin.

SCHEMATIC CROSS SECTION
GUAJIRA BASIN

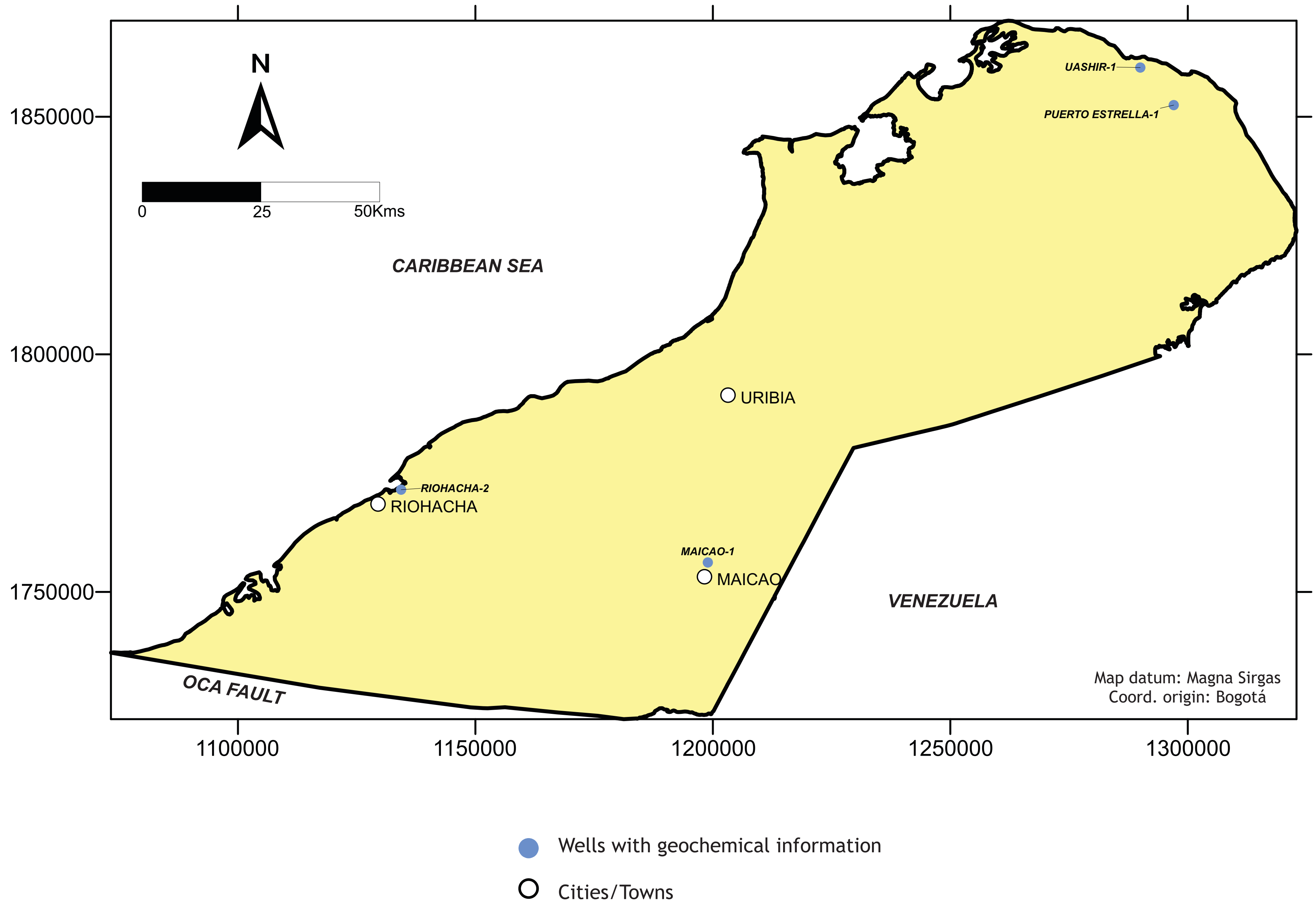


From Barrero et al., 2007



From Barrero et al., 2007

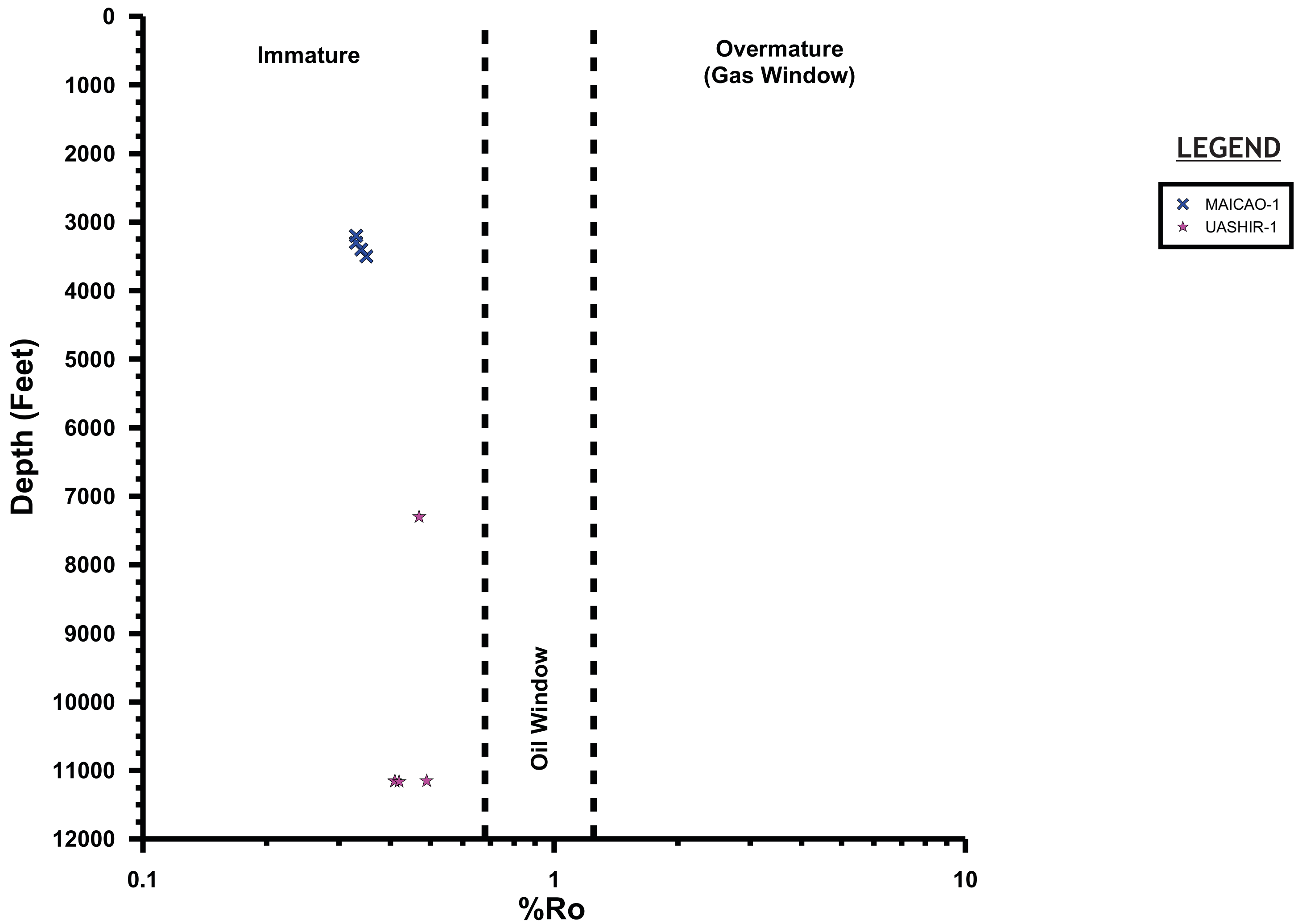
Wells and Seeps



The number of wells and/or surface locations with geochemical information in the Guajira Basin is 4.

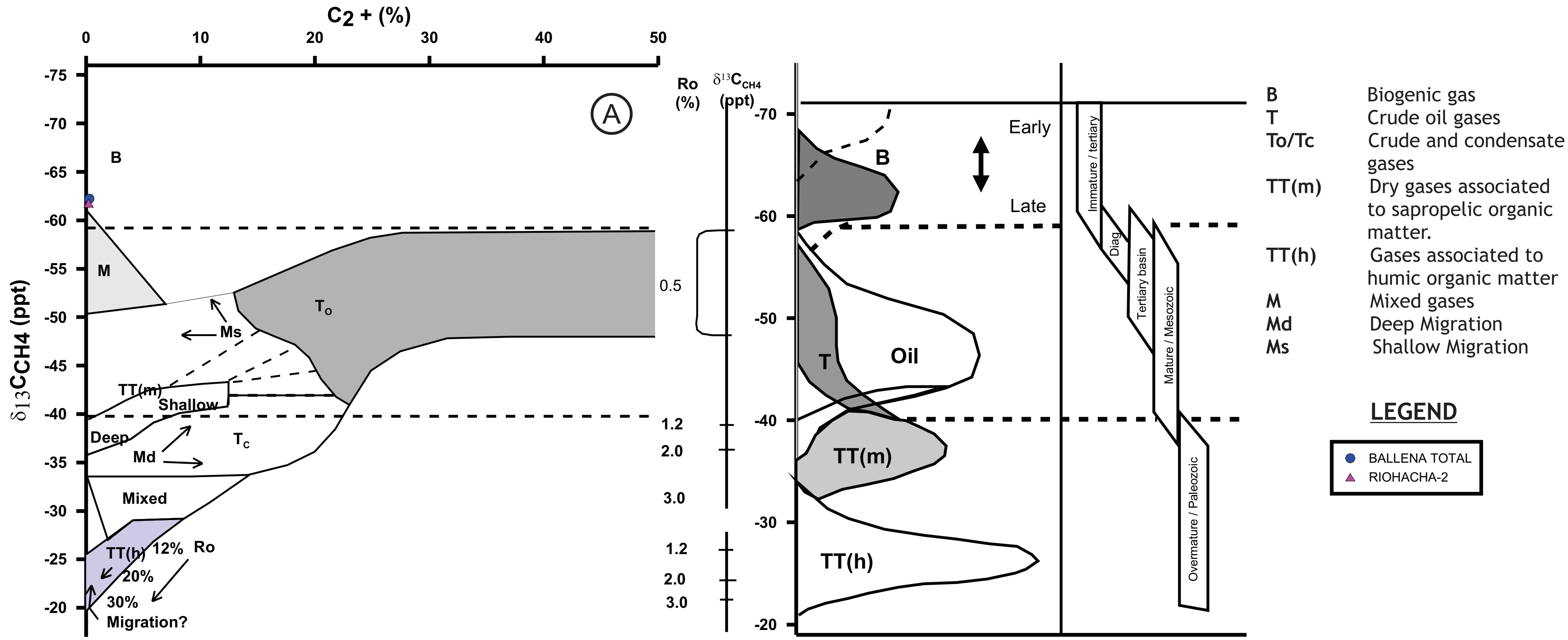
There are no oil and gas seeps reported in this basin.

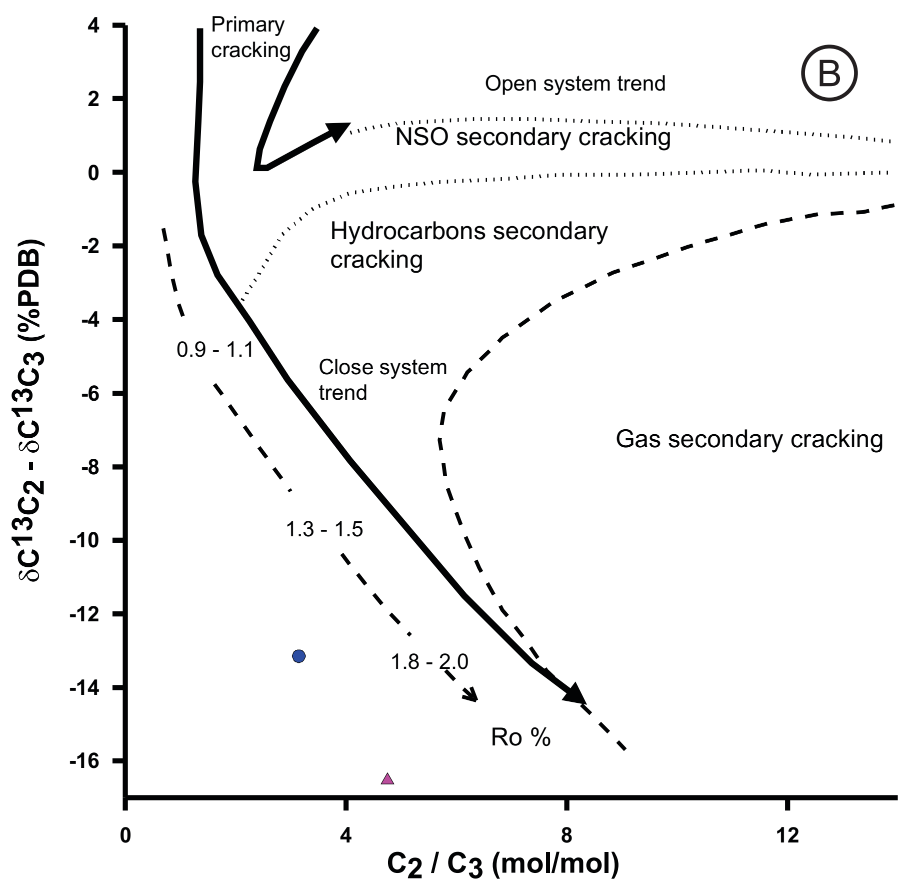
Source Rock Characterization



- The vitrinite reflectance (%Ro) maturity data of the wells sampled in the basin suggests that the stratigraphic sequence is immature.

Gas Characterization

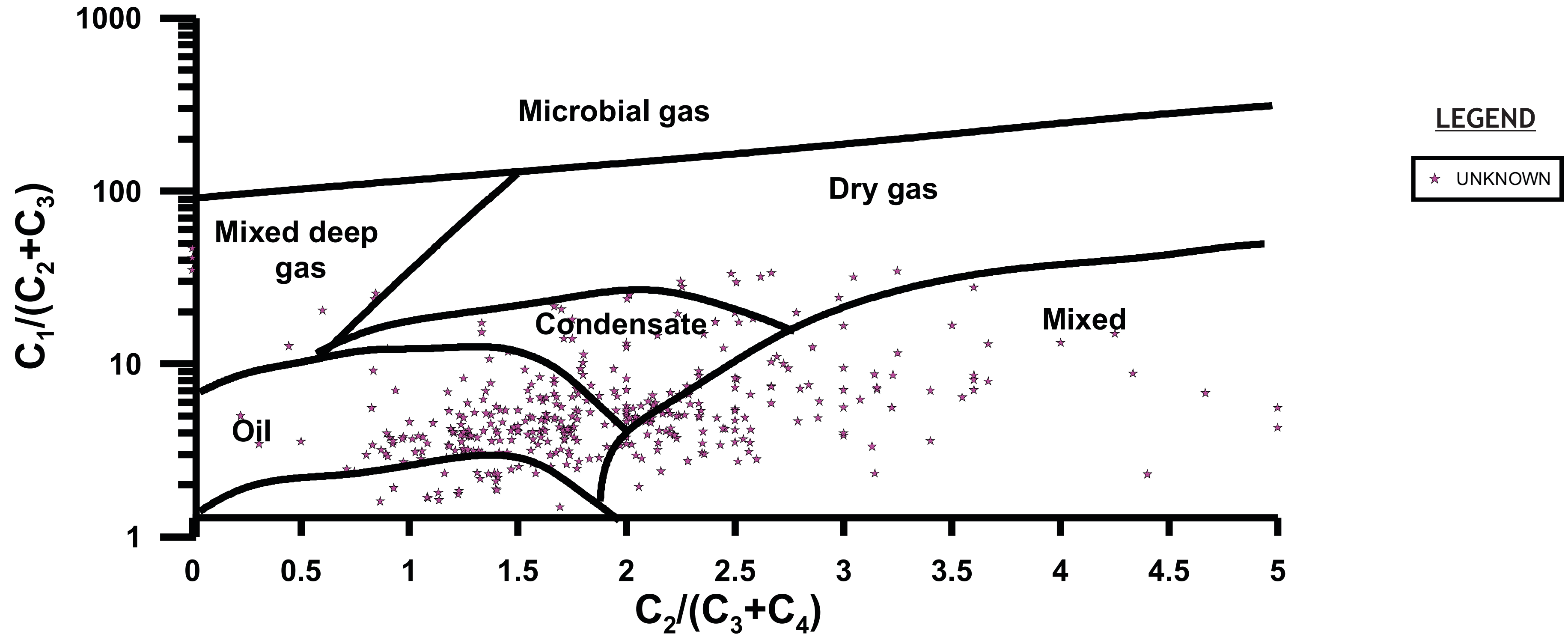




- The C2+ vs d13C CH4 (ppt) and the relationship with organic matter maturity (Schoell, 1983), suggest that the gas samples mainly correspond to biogenic gases.

- The C2/C3 vs d13C C2 - d13C C3 (% PDB) diagram shows that the gases could reach a high thermal state of evolution which contradicts the biogenic character from the C2+ vs d13C CH4 graph.

Surface Geochemistry



Compositional data from surface geochemistry samples indicate that hydrocarbons are thermogenic, formed mainly during oil generation window with minor presence of high maturity hydrocarbons (gas generation window).

Mixing between different thermal maturity hydrocarbons is also indicated by the data.

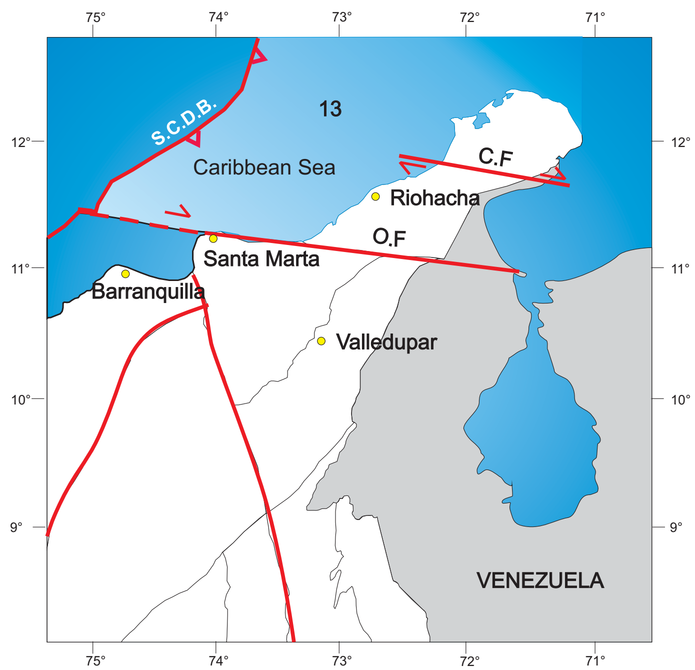
There is no evidence of microbial gas in the basin.

GUAJIRA OFFSHORE BASIN

Generalities
Wells and Seeps
Source Rock Characterization
Gas Characterization

Generalities

GUAJIRA OFFSHORE BASIN LOCATION AND BOUNDARIES



BOUNDARIES

North-Northwest: South Caribbean Deformed Belt deformation front (S.C.D.B.)

East: Colombia-Venezuela border

Southwest: Oca Fault (O.F.)

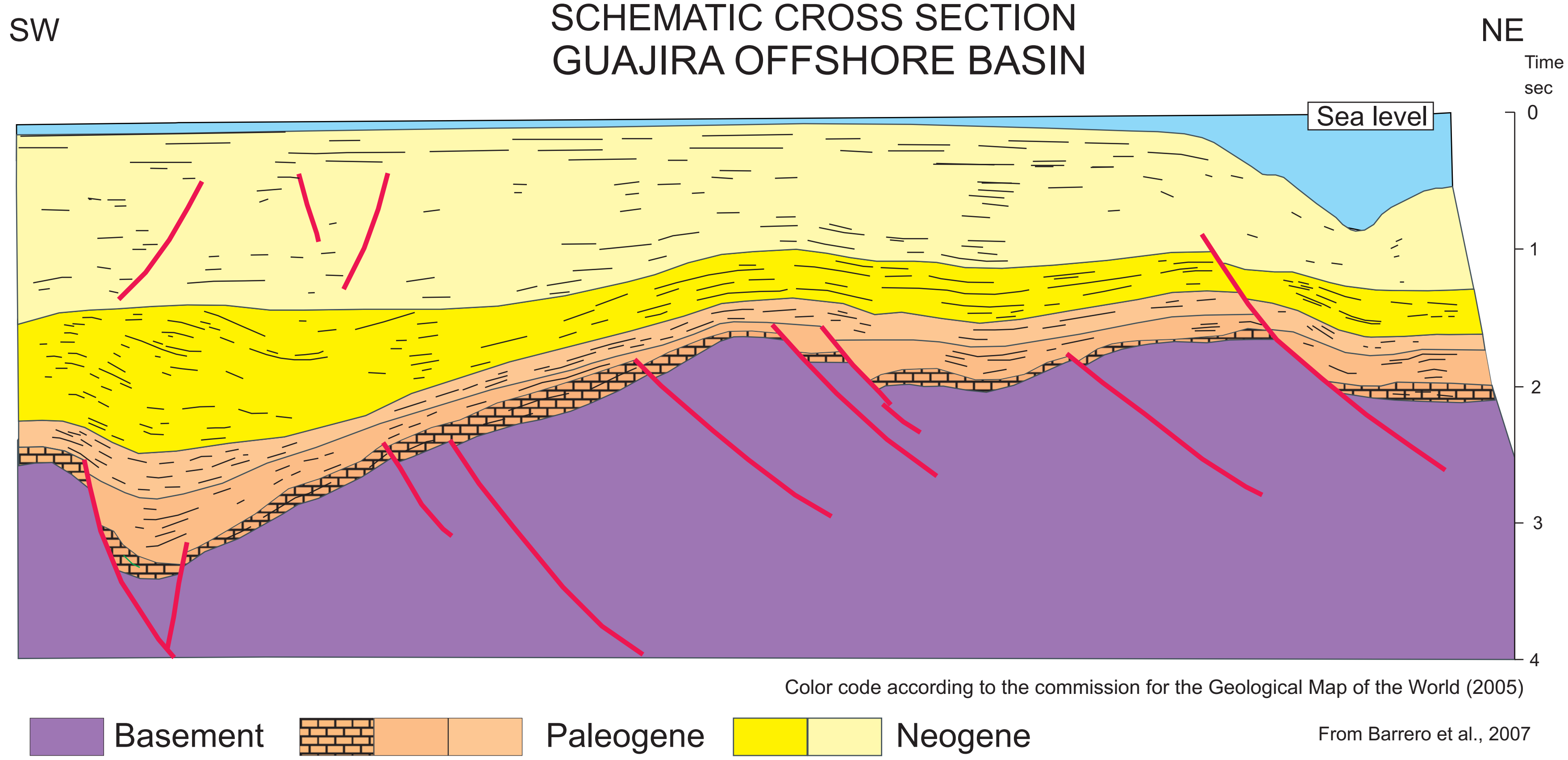
Southeast: Continental Guajira shoreline

From Barrero et al., 2007

The source rock geochemical information interpreted for the Guajira Offshore Basin includes %TOC and Rock-Eval Pyrolysis data from 588 samples taken in 4 wells; additionally 106 organic petrography samples from 4 wells were interpreted.

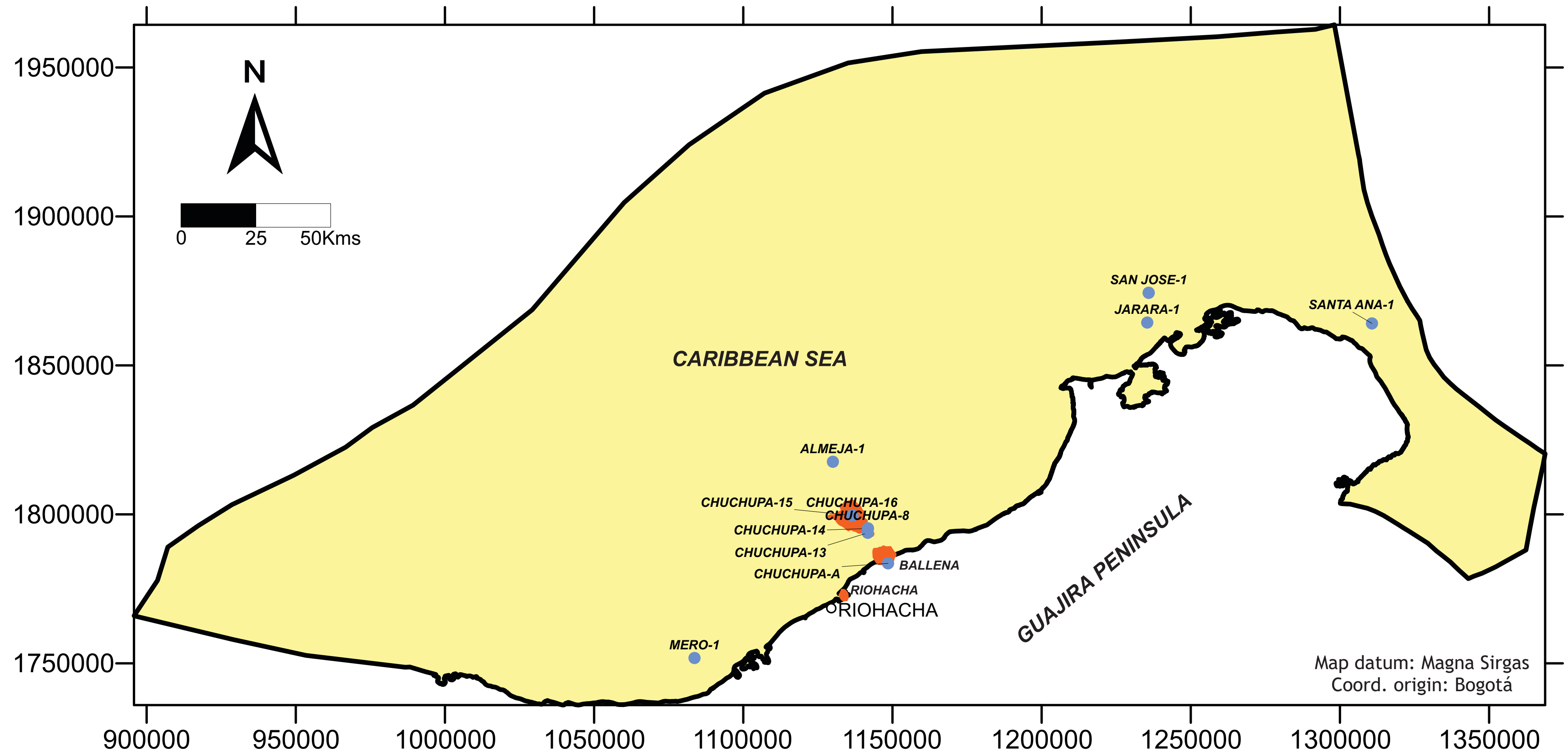
Due to the lack of crude oil geochemical data, crude oil interpretation was not made for the basin.

SCHEMATIC CROSS SECTION GUAJIRA OFFSHORE BASIN



From Barrero et al., 2007

Wells and Seeps



Oil and gas fields

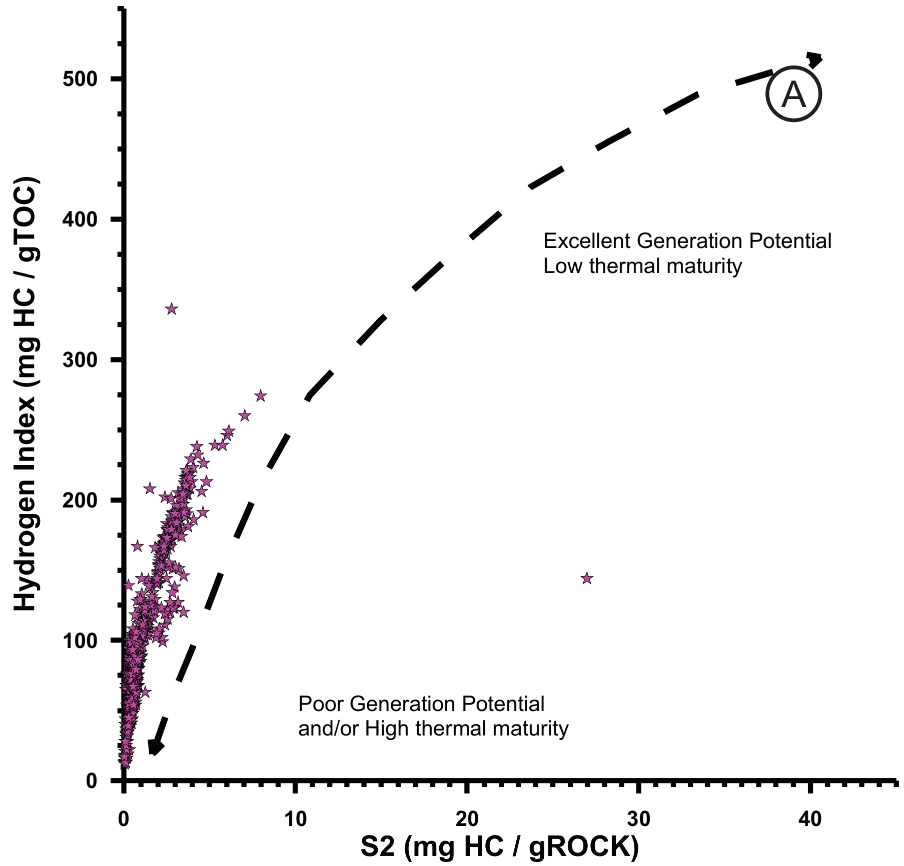
Wells with geochemical information

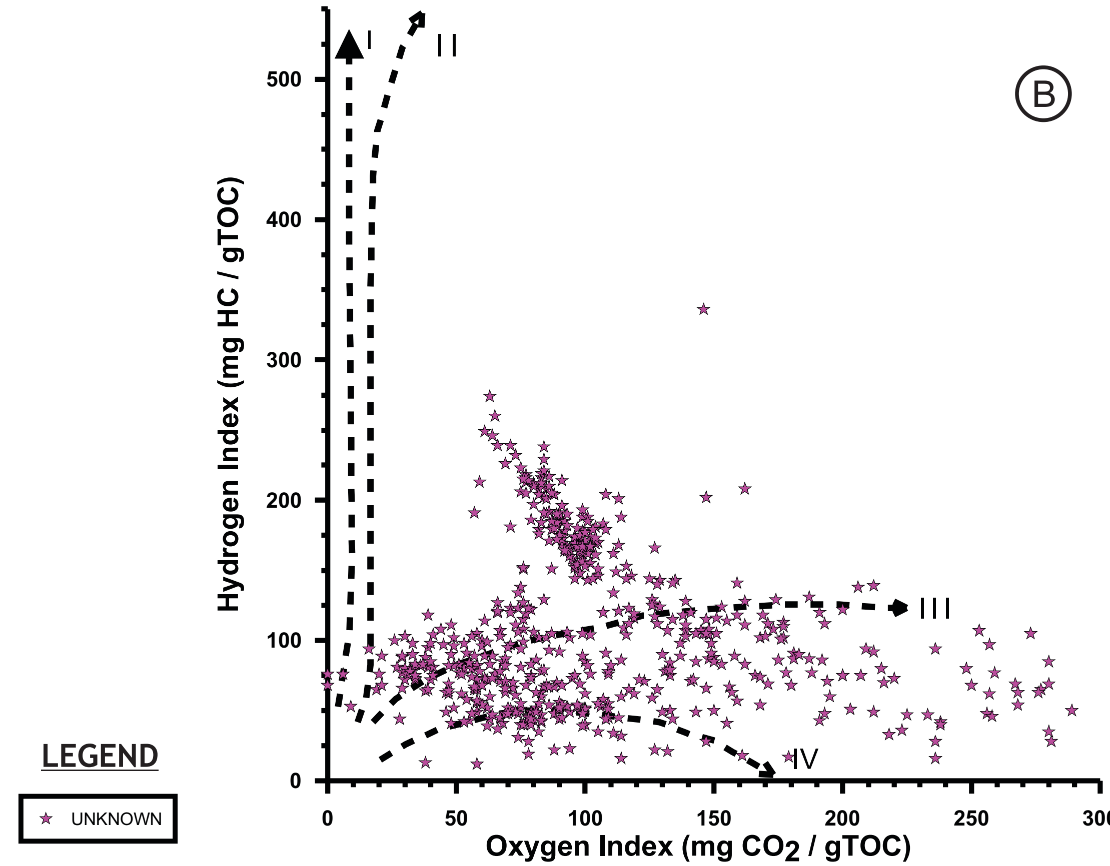
Cities/Towns

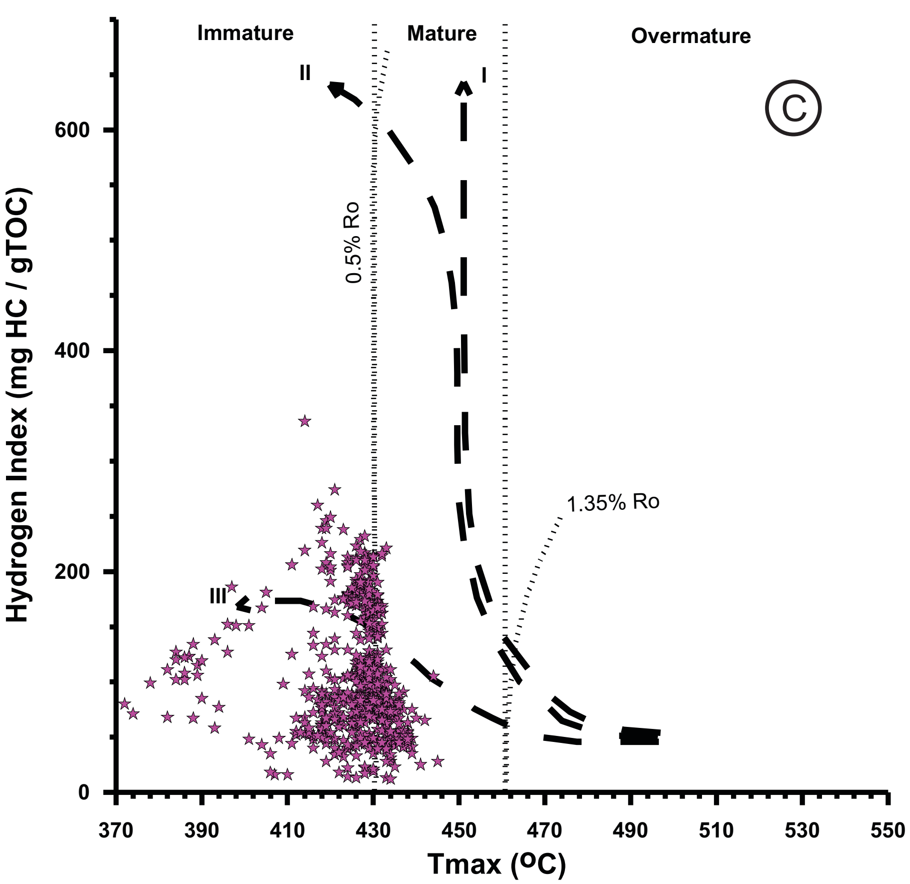
The number of wells and/or surface locations with geochemical information in the Guajira Offshore Basin is 11.

There are no oil and gas seeps reported in this basin.

Source Rock Characterization





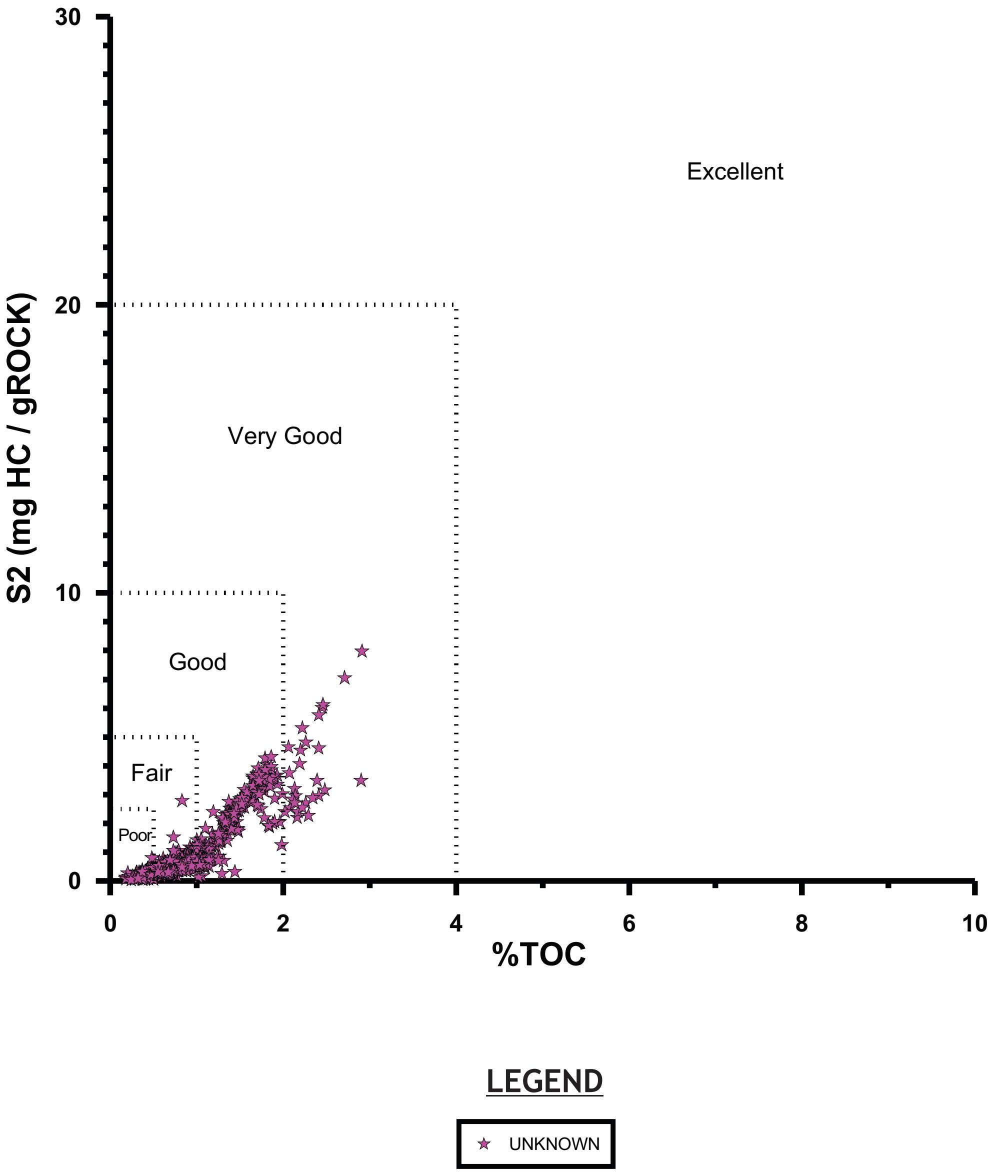


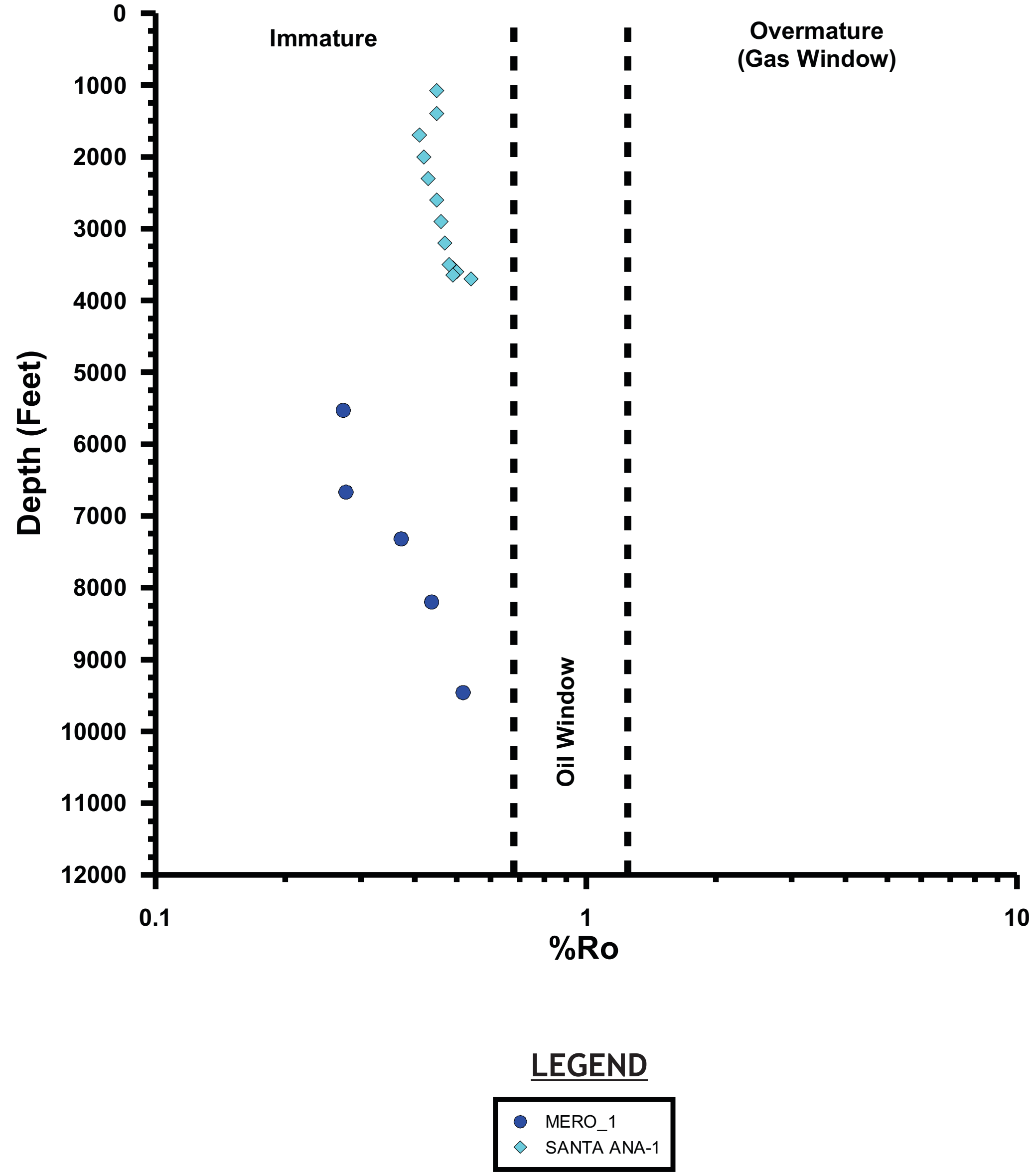
- The data obtained from pyrolysis of rock samples for Hydrogen Index (HI) and S2 peak, indicate that most samples in the basin have poor generation potential (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock), and few good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock). (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that the rock samples in the basin have values indicative of type III gas-prone kerogen to type IV kerogen. (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that the samples from the sedimentary sequence in the basin are immature to early mature for hydrocarbons generation (Figure C).

Source Rock Characterization

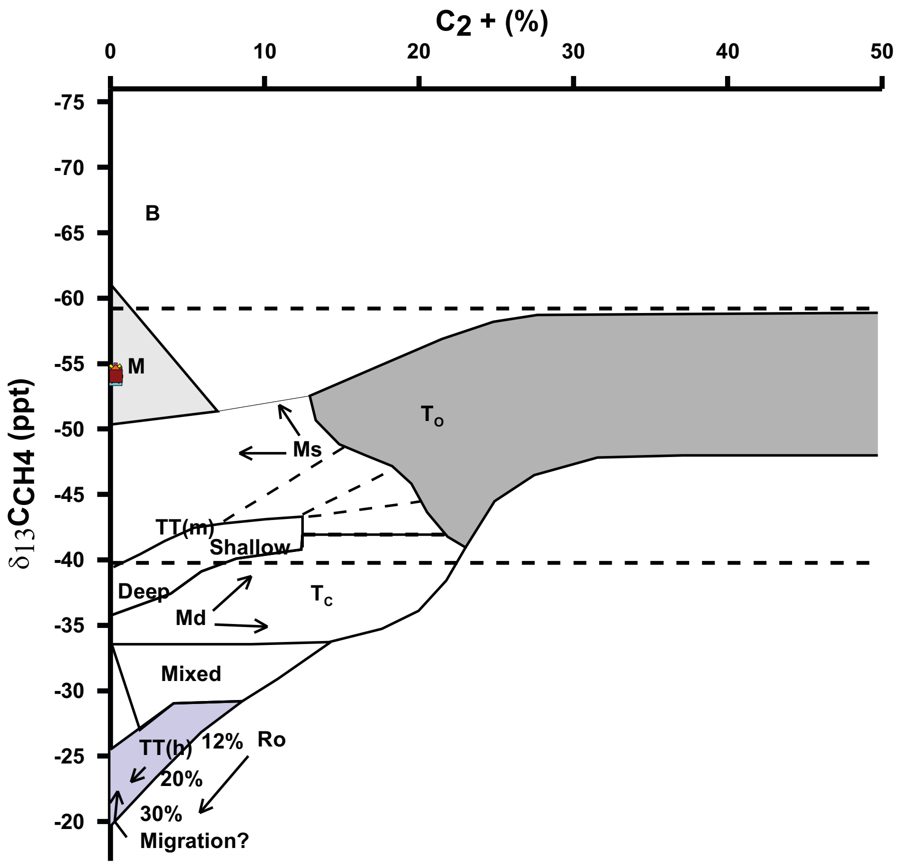


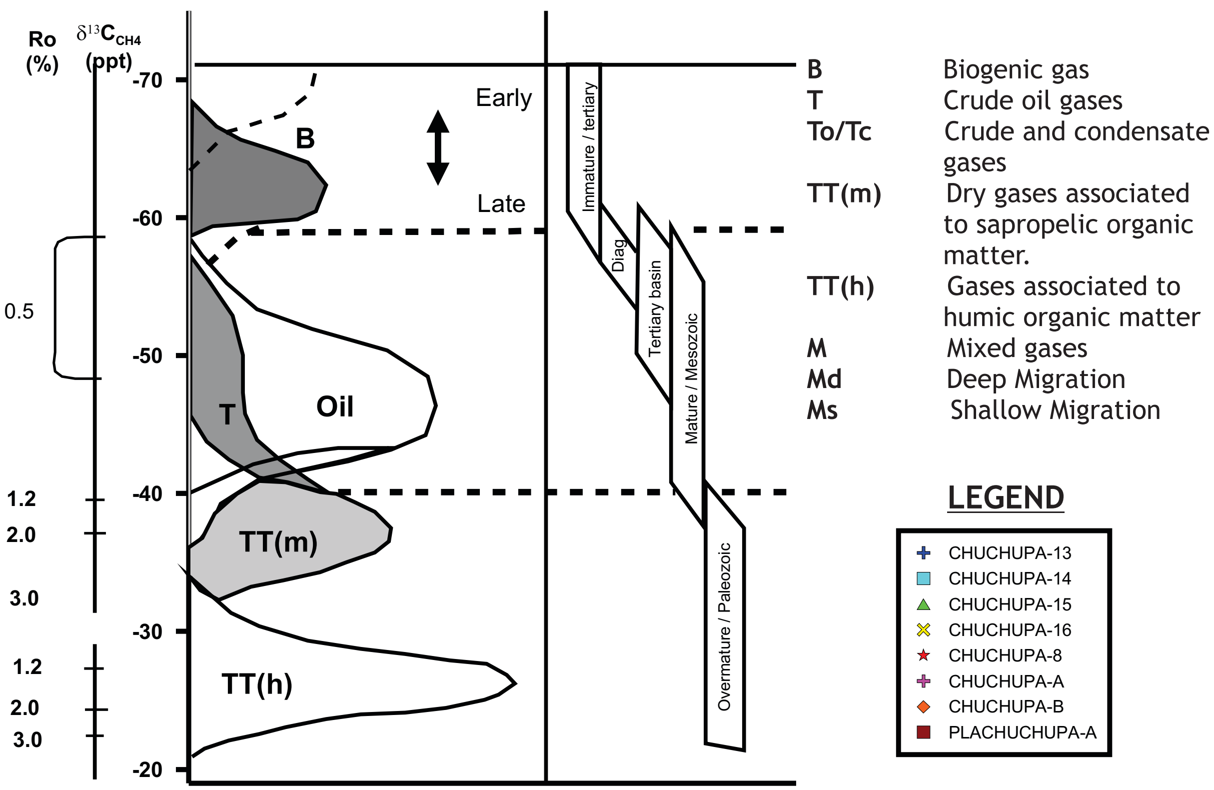


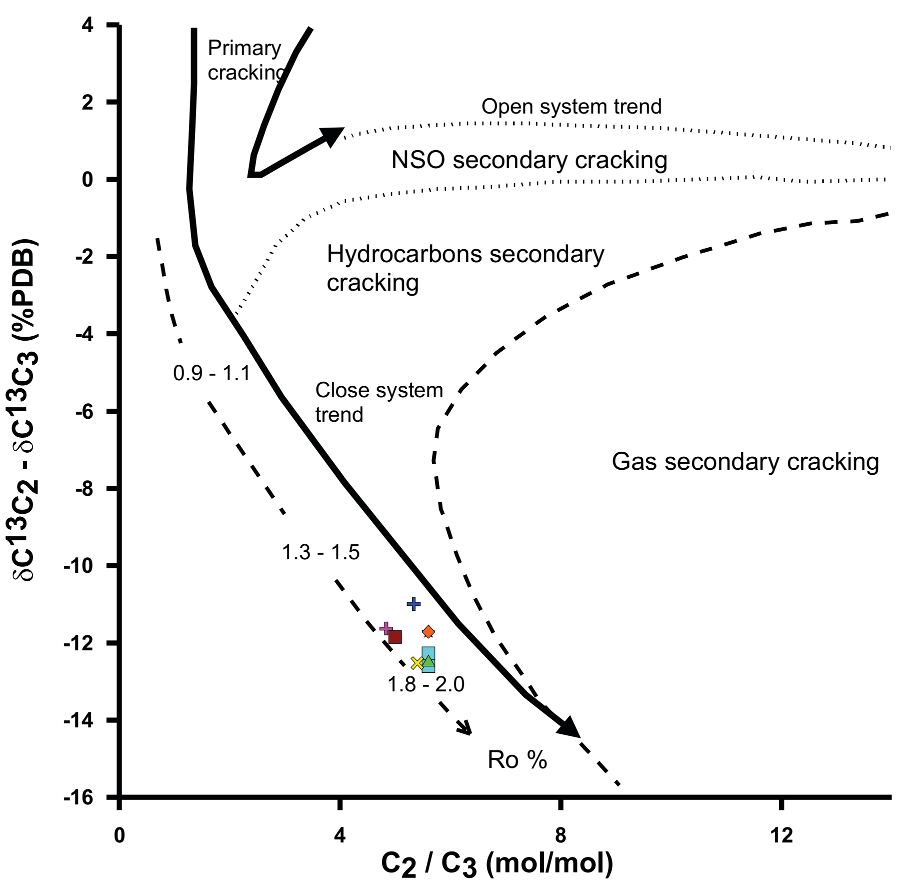
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there is a widespread distribution of samples from poor oil generation potential (S2 < 5 mg HC/g rock and %TOC < 1) to very good oil generation potential (S2 up to 10 mg HC/g rock and % TOC up to 3) (Figure A).

-The vitrinite reflectance (%Ro) information from two wells shows that the sedimentary sequence is immature, however Tmax maturity data indicate that early maturity have been reached in the basin, and that along with the type III kerogen indicated by the pyrolysis data could explain the gas accumulations found in the basin (Figure B).

Gas Characterization







- The C2+ vs d13C CH4 (ppt) and the relationship with organic matter maturity (Schoell, 1983), suggest that the gas samples mainly correspond to a mixture of gases (thermogenic with possible biogenic input).

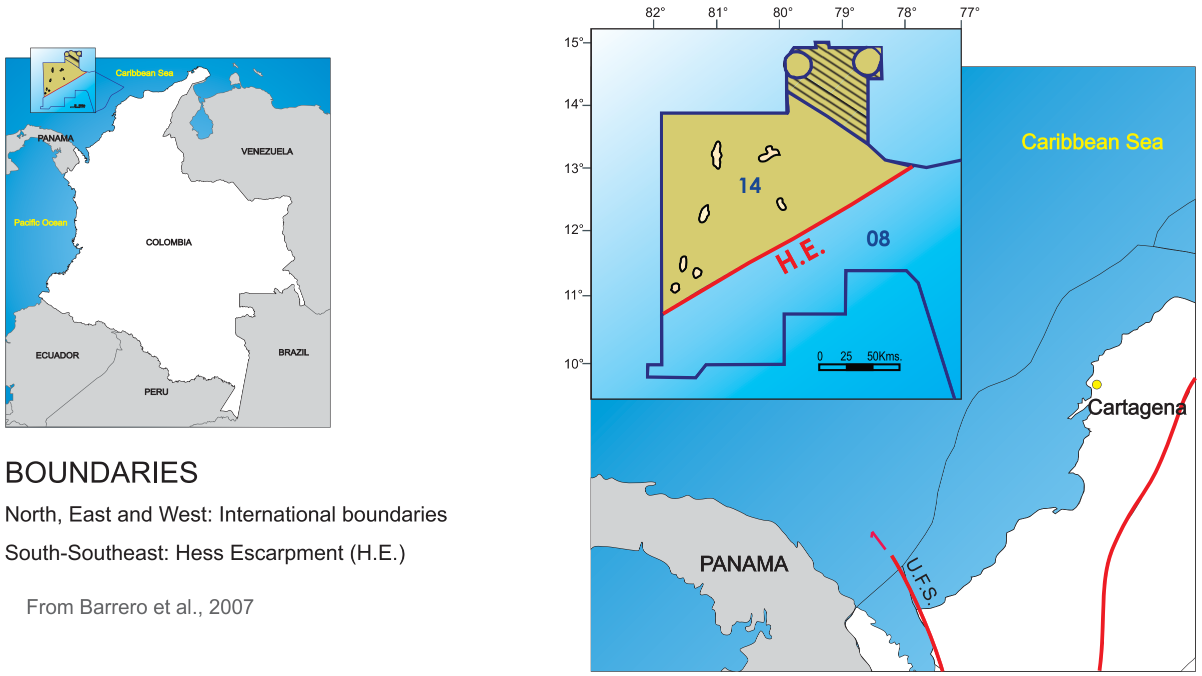
- The C2/C3 vs d13C C2 - d13C C3 (% PDB) diagram shows that the gases could reach a high thermal state of evolution, but maturity data (Tmax and %Ro) do not support this, suggesting that there is a source rock that has higher thermal maturity but has not been reached by the wells drilled in the basin.

LOS CAYOS BASIN

Generalities
Source Rock Characterization

Generalities

LOS CAYOS BASIN
LOCATION AND BOUNDARIES



Colombia-Jamaica Join Regime Area

BOUNDARIES

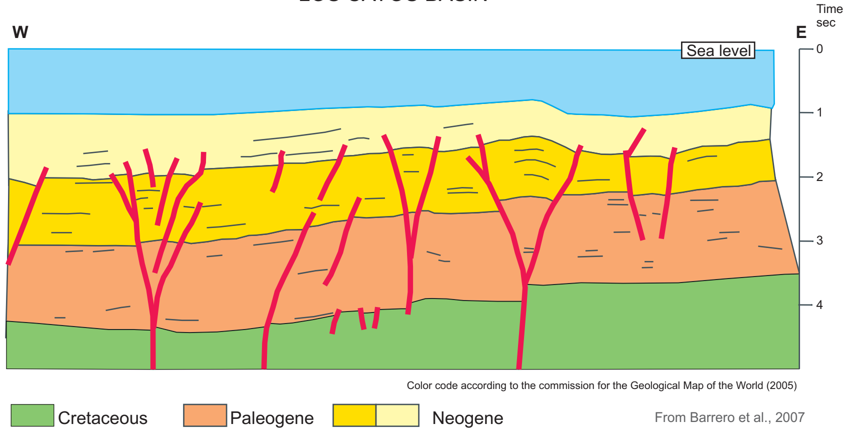
North, East and West: International boundaries

South-Southeast: Hess Escarpment (H.E.)

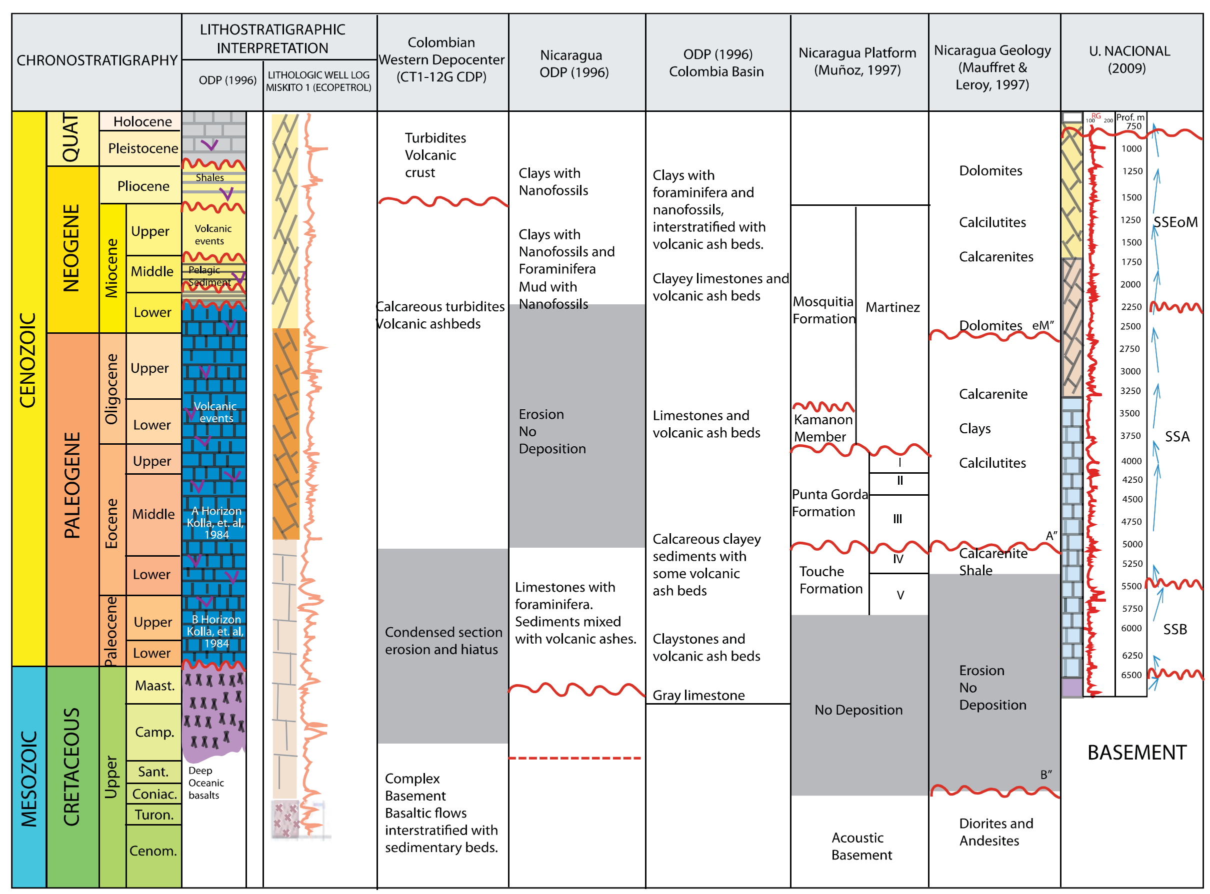
From Barrero et al., 2007

The source rock geochemical information interpreted for the Cayos Basin includes %TOC and Rock-Eval Pyrolysis data from 50 samples taken in the Perlas-3 well located in the Nicaraguan shelf.

SCHEMATIC CROSS SECTION
LOS CAYOS BASIN

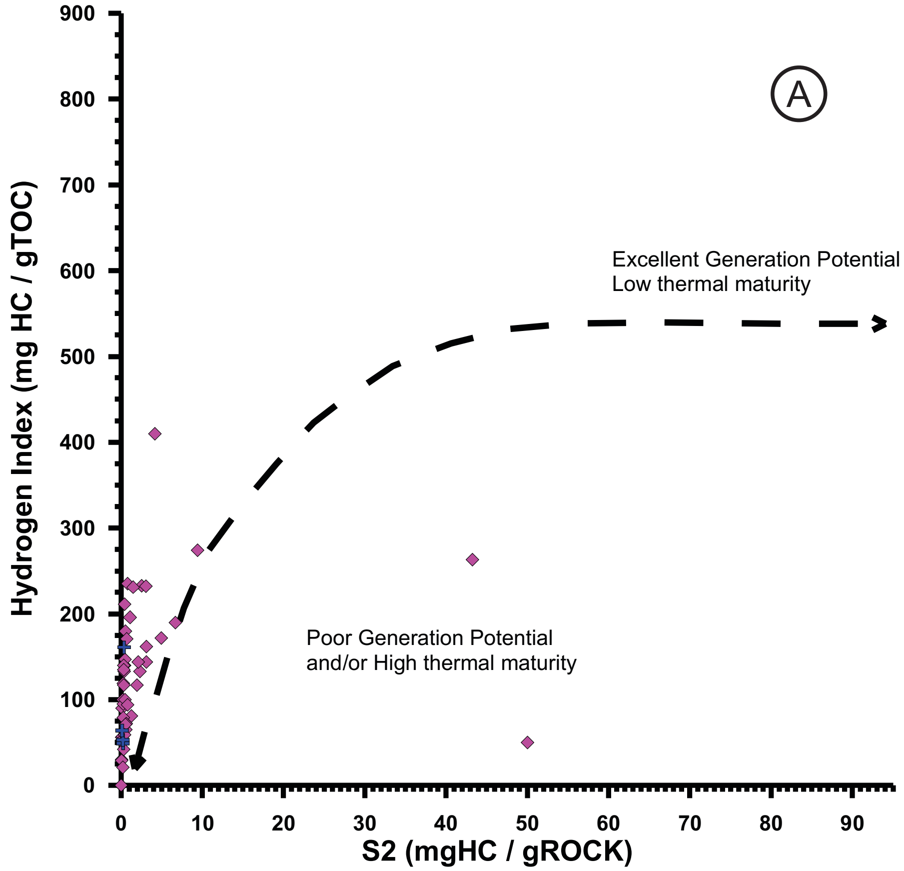


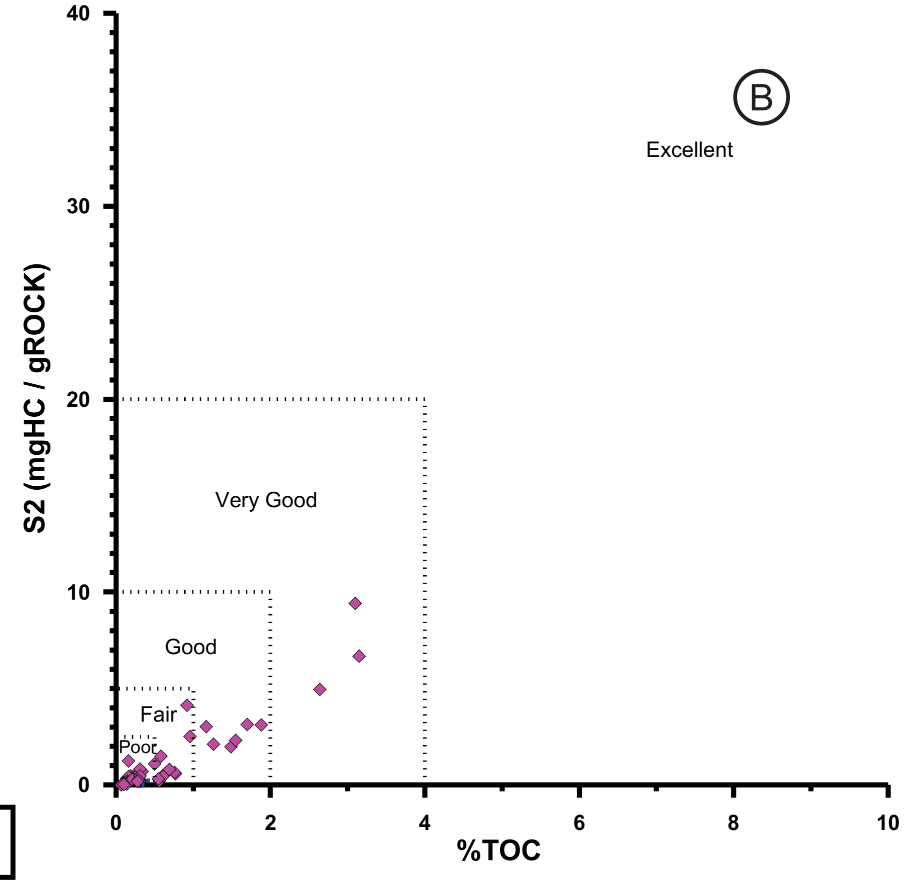
From Barrero et al., 2007

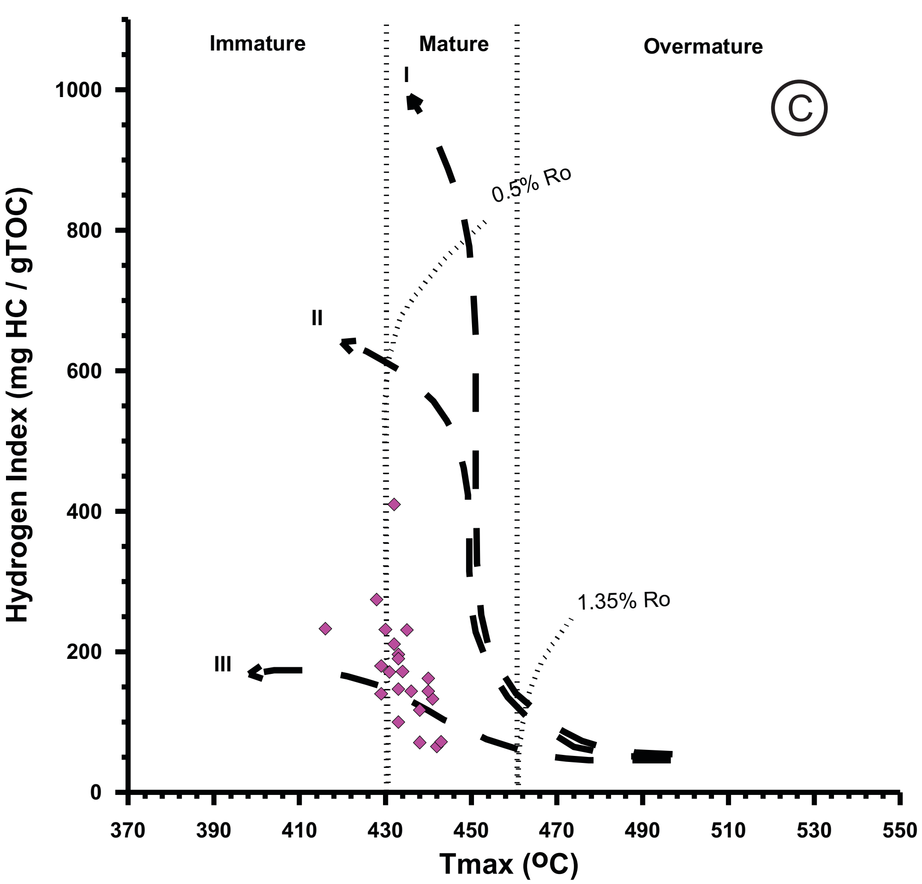


From Mojica et al., 2010

Source Rock Characterization





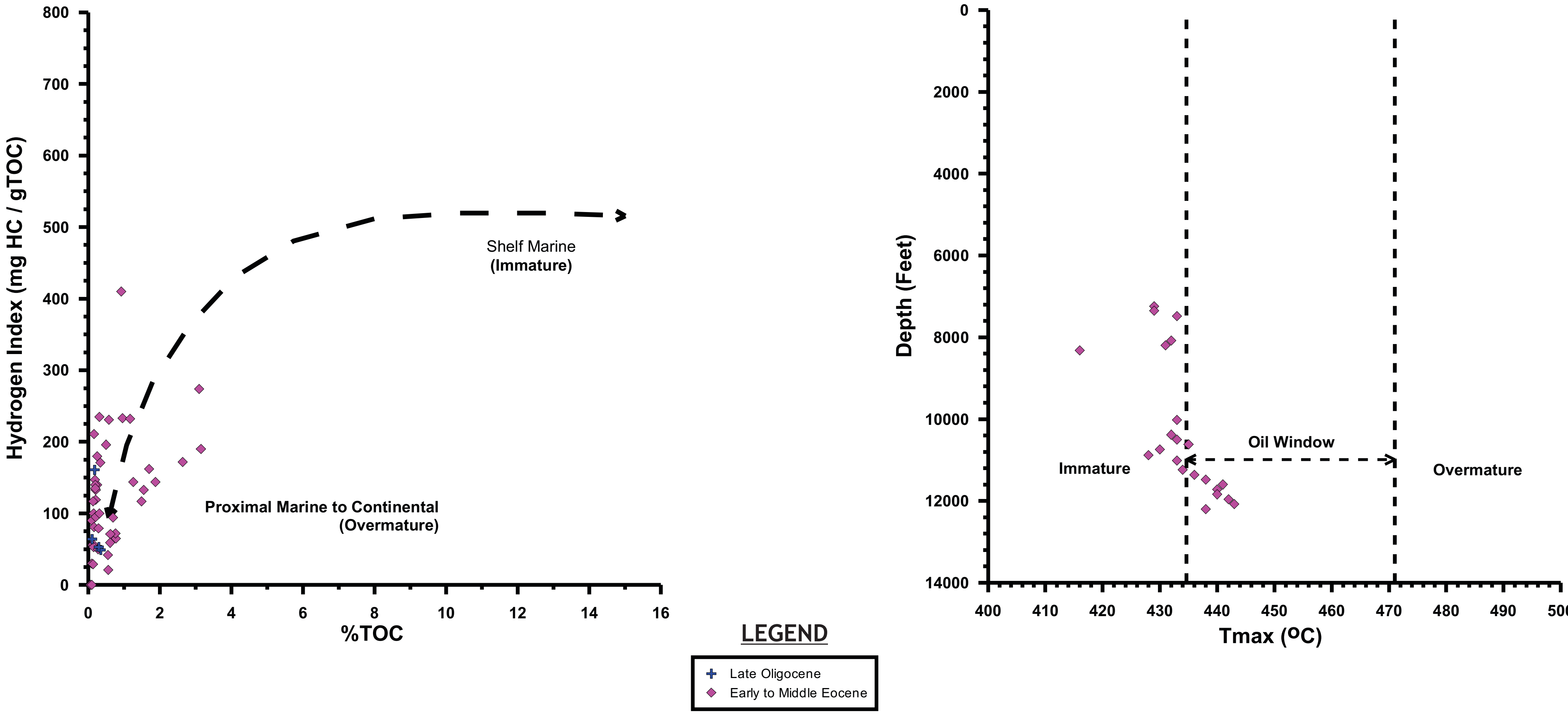


- The data obtained from pyrolysis of rock samples for Hydrogen Index (HI) and S2 peak, indicate that in general the samples from Early to Middle Eocene and Late Oligocene rocks have poor generation potential (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock), and few Early to Middle Eocene samples have good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock) (Figure A).

- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, the graph shows that there are samples from Early to Middle Eocene rocks with good to very good oil generation potential (S2 up to 10 mg HC/g rock and % TOC up to 4)(Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that most samples from Early to Middle Eocene rocks have reached early maturity to oil generation peak conditions in the Nicaraguan shelf to the west of the basin (Figure C). Additionally the Hydrogen Index values suggests the presence of type II and III kerogens in these rocks.

Source Rock Characterization



- The Hydrogen Index vs Organic content (%TOC) graph shows that samples from Early to Middle Eocene rocks have the best source characteristics (Hydrogen Index values > 200 mg HC/g TOC and %TOC >2) but are very few samples to establish the real potential of this sedimentary sequence. Considering that the samples taken in the well Perlas-3 have not reach high thermal maturity the data could indicate that these Eocene rocks were deposited in a proximal marine to continental depositional environments(Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence enters the oil generation window at approximately 11000 feet in the Nicaraguan shelf, and that the samples reach an early maturity condition (Figure B).

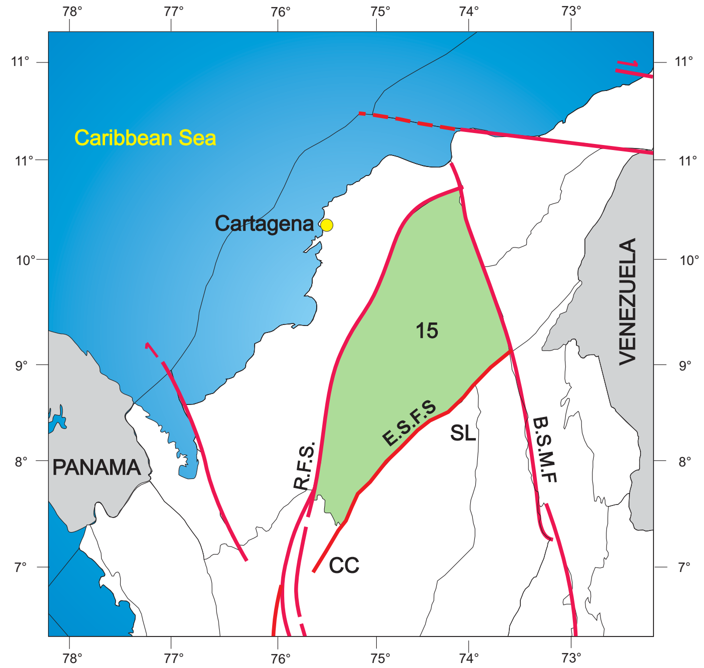
- In summary, the best source rock close to Los Cayos basin are the Early to Middle Eocene rocks found in the Perlas-3 well drilled in the Nicaraguan shelf. However this information is too scarse to have a real picture on the potential source rocks in the basin.

LOWER MAGDALENA VALLEY BASIN

Generalities
Wells and Seeps
Crude Oil Quality
Depositional Environments
Chromatography
Source Rock Characterization
Gas Characterization
Surface Geochemistry

Generalities

LOWER MAGDALENA VALLEY BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

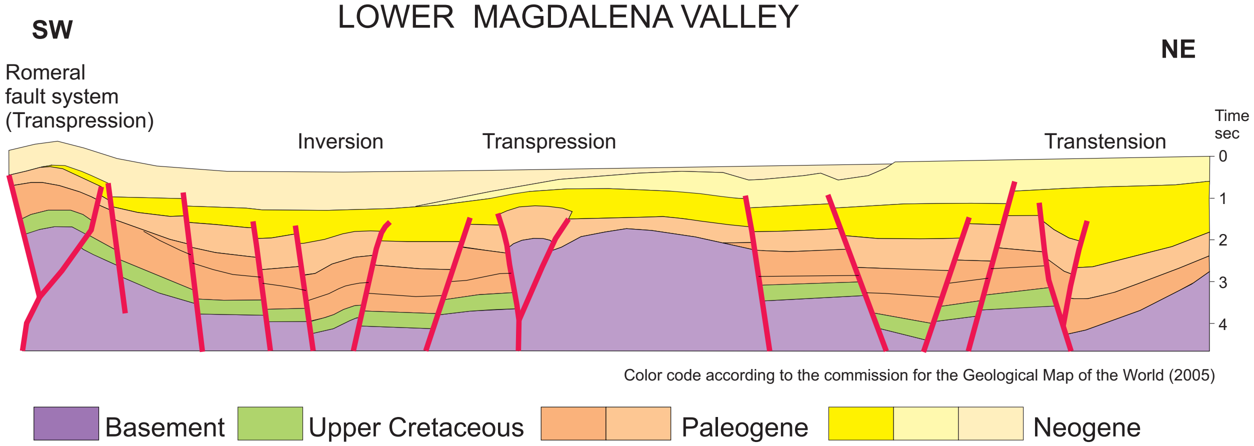
North: Romeral fault system (R.F.S)
East: Bucaramanga-Santa Marta fault system (B.S.M.F.)
South and Southeast: Central Cordillera(CC) and Serranía de San Lucas (SL) Pre-Cretaceous rocks
West: Romeral fault system (R.F.S.)

From Barrero et al., 2007

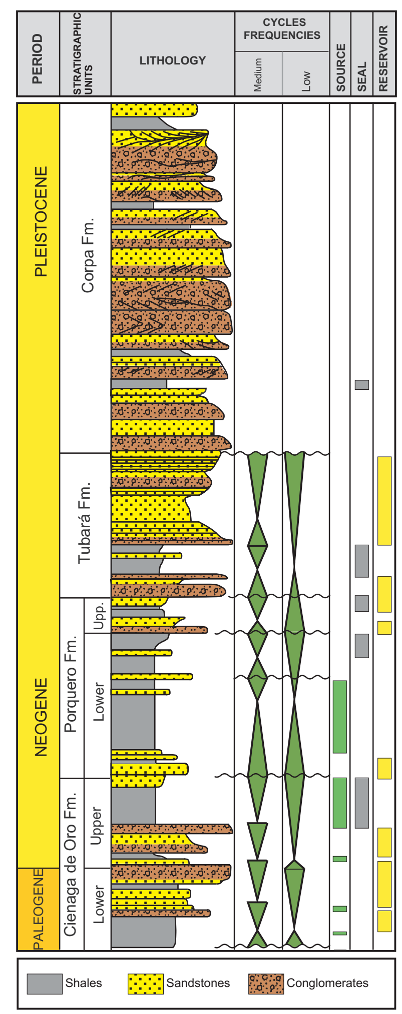
The source rock geochemical information interpreted for the Lower Magdalena Valley Basin includes %TOC and Rock-Eval Pyrolysis data from 973 samples taken in 52 wells; additionally 179 organic petrography samples from 30 wells were interpreted.

Crude oil and extracts information from 16 bulk analysis samples, 177 liquid chromatography samples, 694 gas chromatography samples, 15 biomarker samples,64 isotopes samples and 191 surface geochemistry samples were also interpreted.

SCHEMATIC CROSS SECTION
LOWER MAGDALENA VALLEY

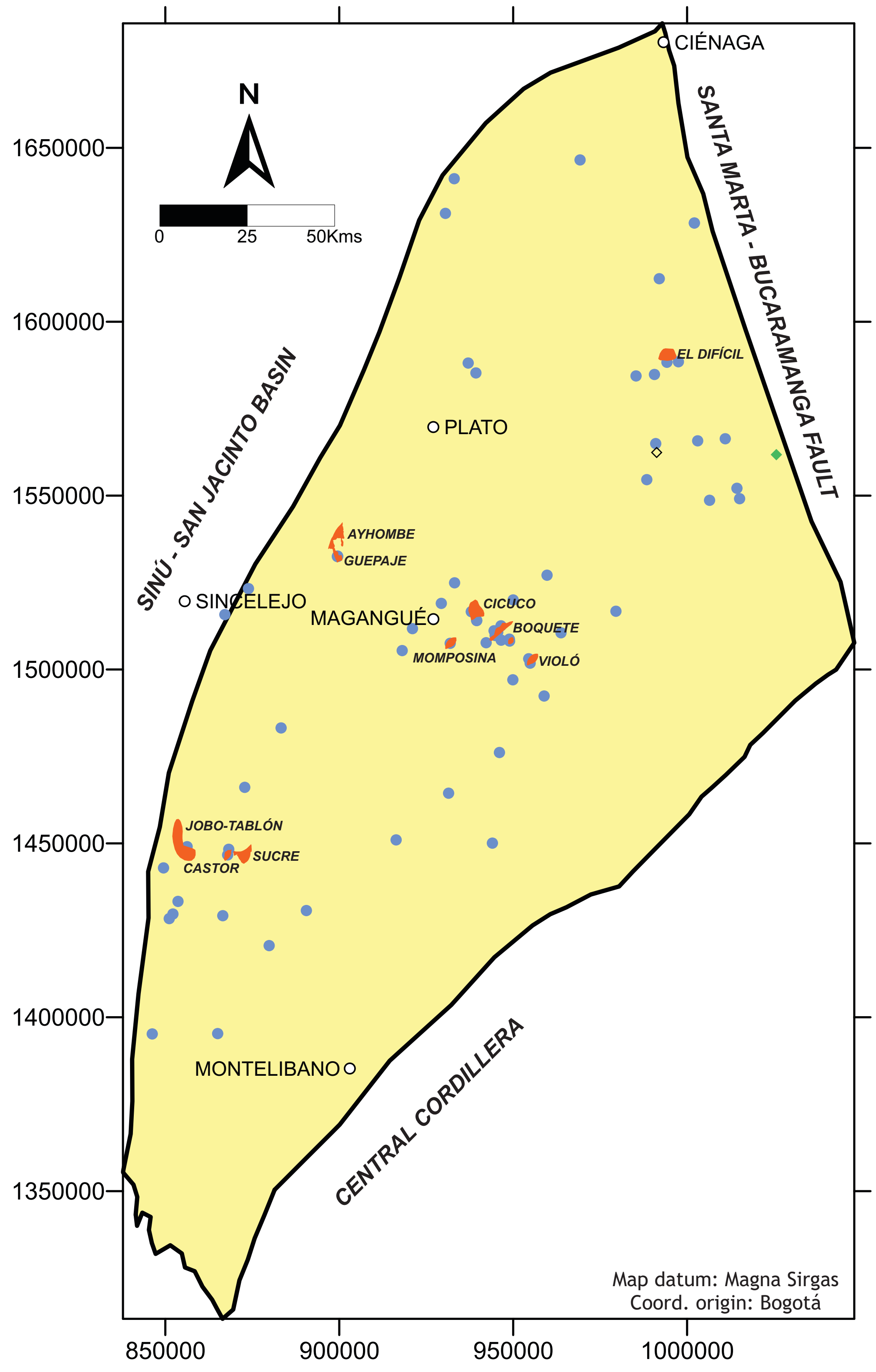


From Barrero et al., 2007



From Barrero et al., 2007

Wells and Seeps

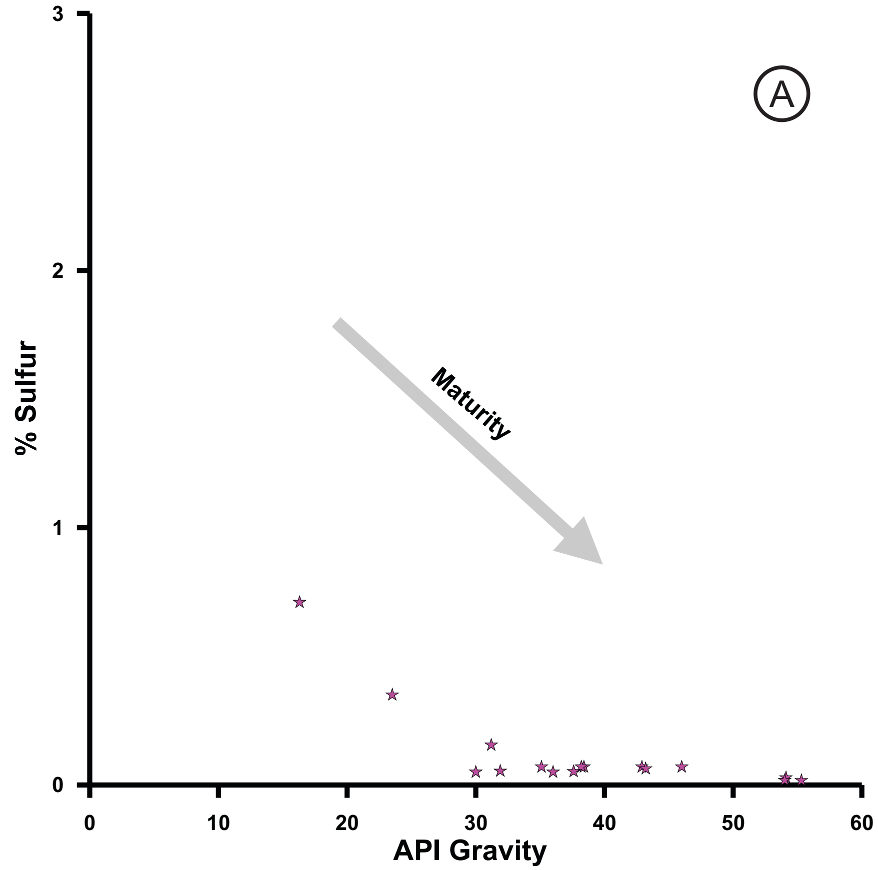


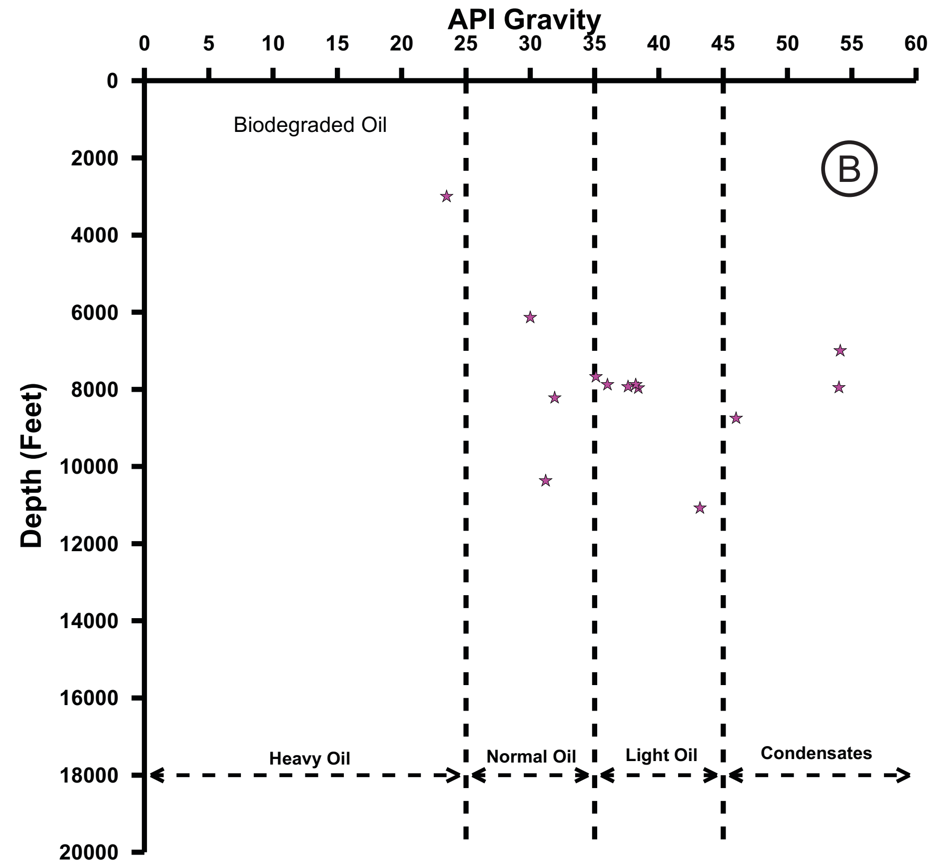
The number of wells and/or surface locations with geochemical information in the Lower Magdalena Valley Basin is 67.

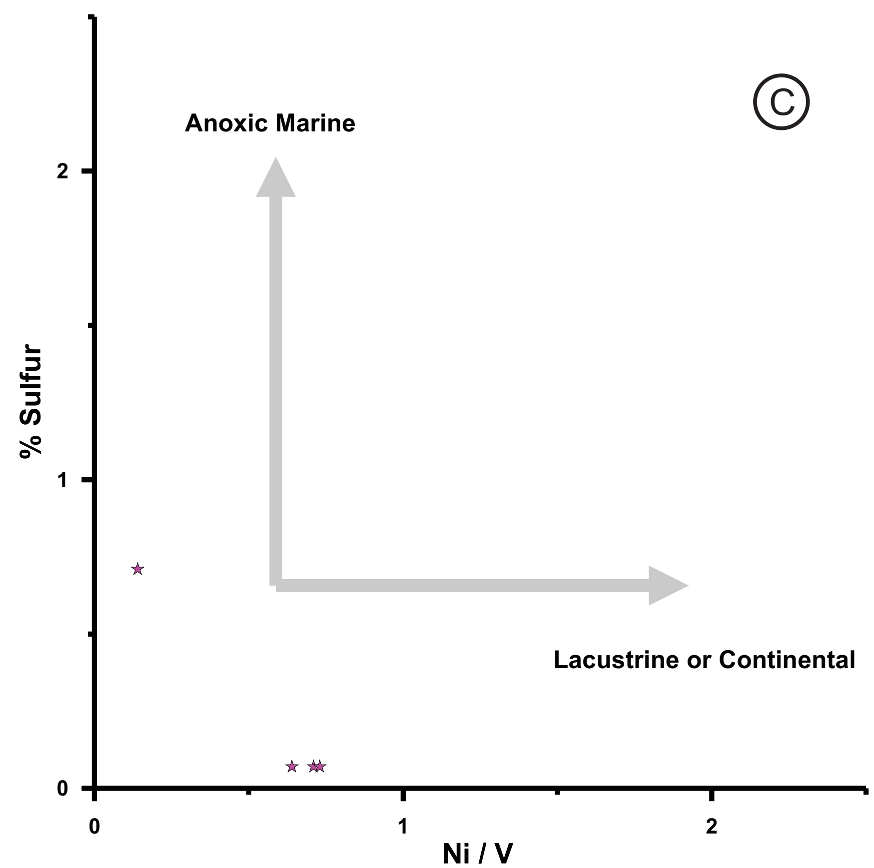
Oilseeps are reported at the northern part of the basin, close to the Santa Marta - Bucaramanga Fault.

- Oil and gas fields
- Wells with geochemical information
- Oil seeps
- Undetermined seeps
- Cities/Towns

Crude Oil Quality





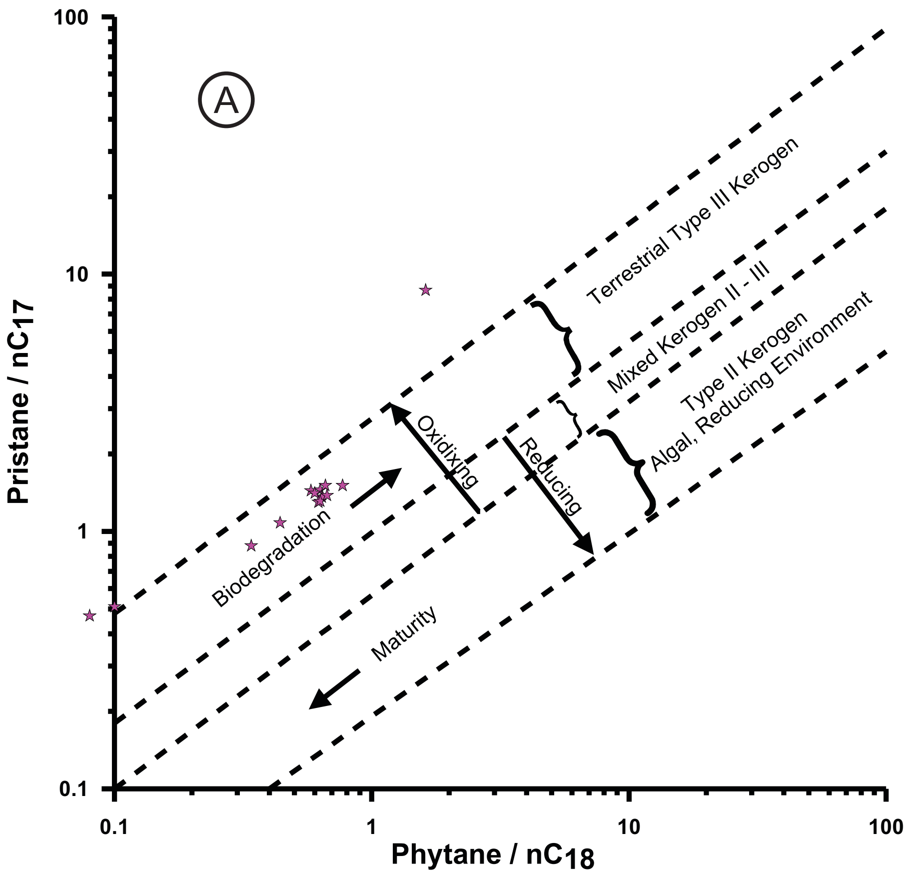


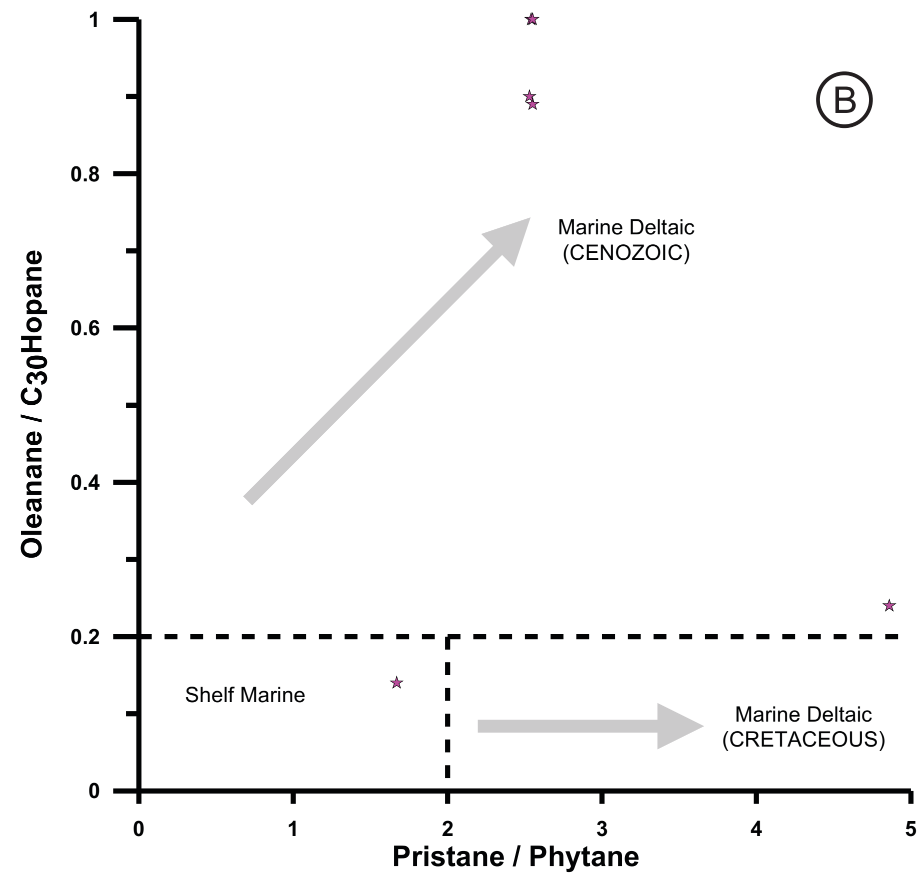
- Crude oils with API gravities ranging from 25° to 55° and sulfur content below 1% are present in the basin. Light and condensate oils predominate in the basin and there is good correlation between sulfur and API gravity, with low API gravity oils having higher sulfur contents than high API gravity oils. The high API gravity of the oils also suggests that they are generated from high thermal maturity source rocks in the basin (Figure A).

- There is no direct relationship between depth and crude oil quality, indicating that similar quality oils can be found at different stratigraphic levels, probably related to vertical migration along faults. But additionally there is the fact that different API gravity oils can be found at similar depths, reflecting different preservation (biodegradation) and/or thermal maturities (Figure B).

- The sulfur content of crude oils is lower than 1%, and its Ni/V ratio below 1, suggesting that they are produced from rocks deposited in a marine suboxic environment with terrigenous organic matter input (Figure C).

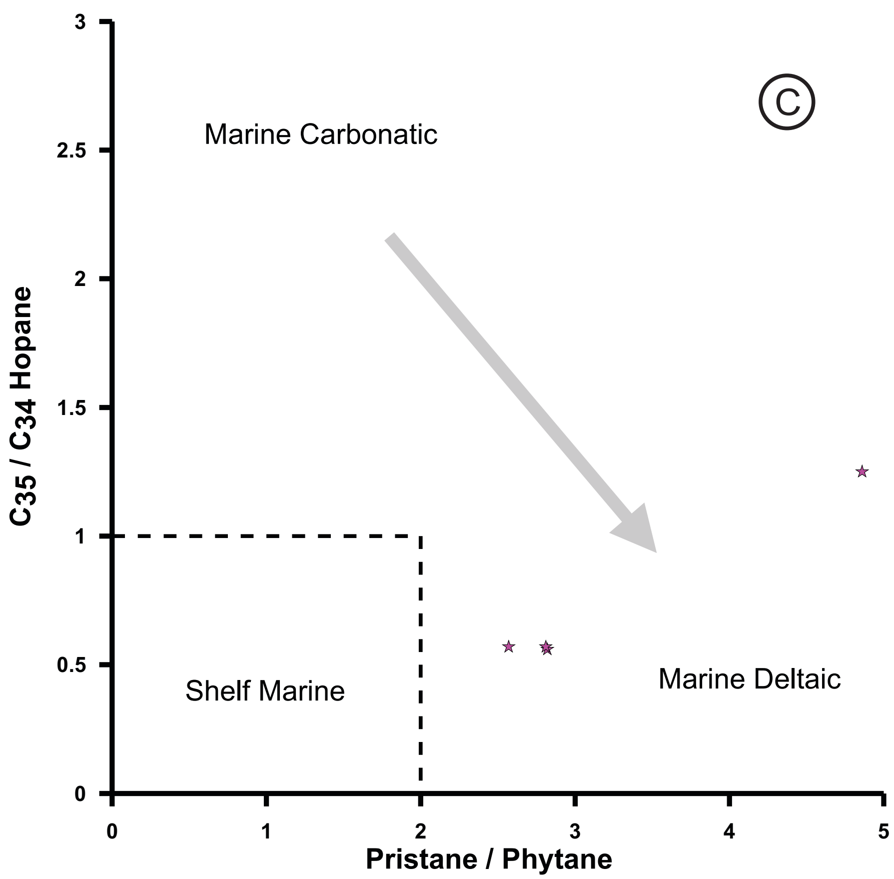
Depositional Environments





LEGEND

★ UNKNOWN

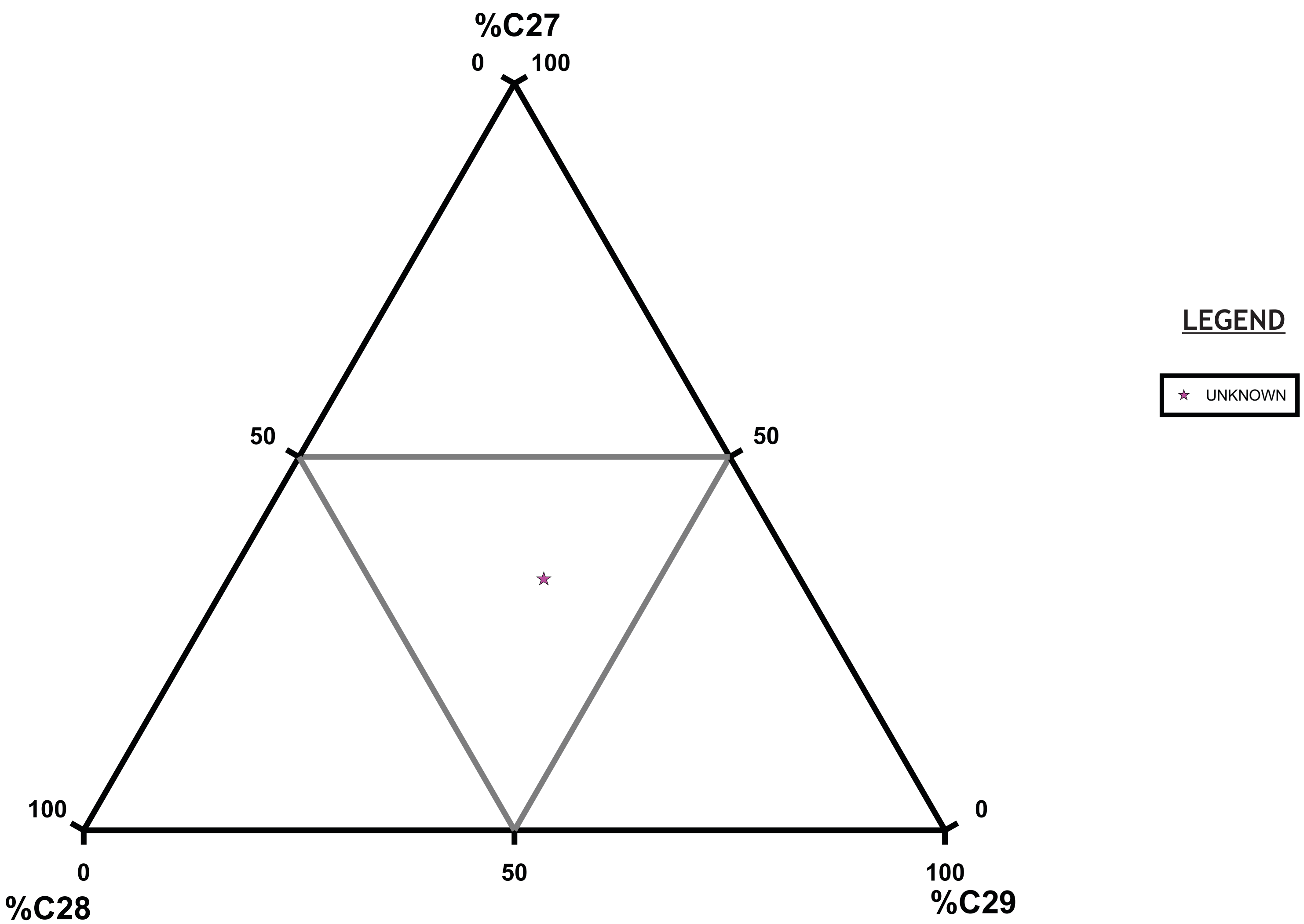


- The Phytane/nC18 vs Pristane/nC17 graph indicates that the oils have origin from terrestrial organic matter (Type III kerogen) deposited in an oxidizing environment and have suffered low biodegradation (Figure A).

- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that most of the oils have high oleanane index values (>0.2) and Pr/Ph values (>2), which indicates that these oils are generated from source rocks deposited in marine deltaic environments. There is one sample with low oleanane index values and Pr/Ph (<2), indicating that this oil was generated from source rocks deposited in a shelf marine environment. The oleanane index has been also used as an age indicator of the source rock, with high oleanane values for oils generated in Cenozoic rocks and low oleanane values in oils from older rocks (Figure B).

- The Pristane/Phytane vs C35/C34 Hopane (Homohopane index) graph shows that oil samples have Pr/Ph values above 2 and C35/C34 Hopane below 1, indicating that these oils were generated from siliciclastic rocks deposited in a marine deltaic environment. (Figure C).

Depositional Environments



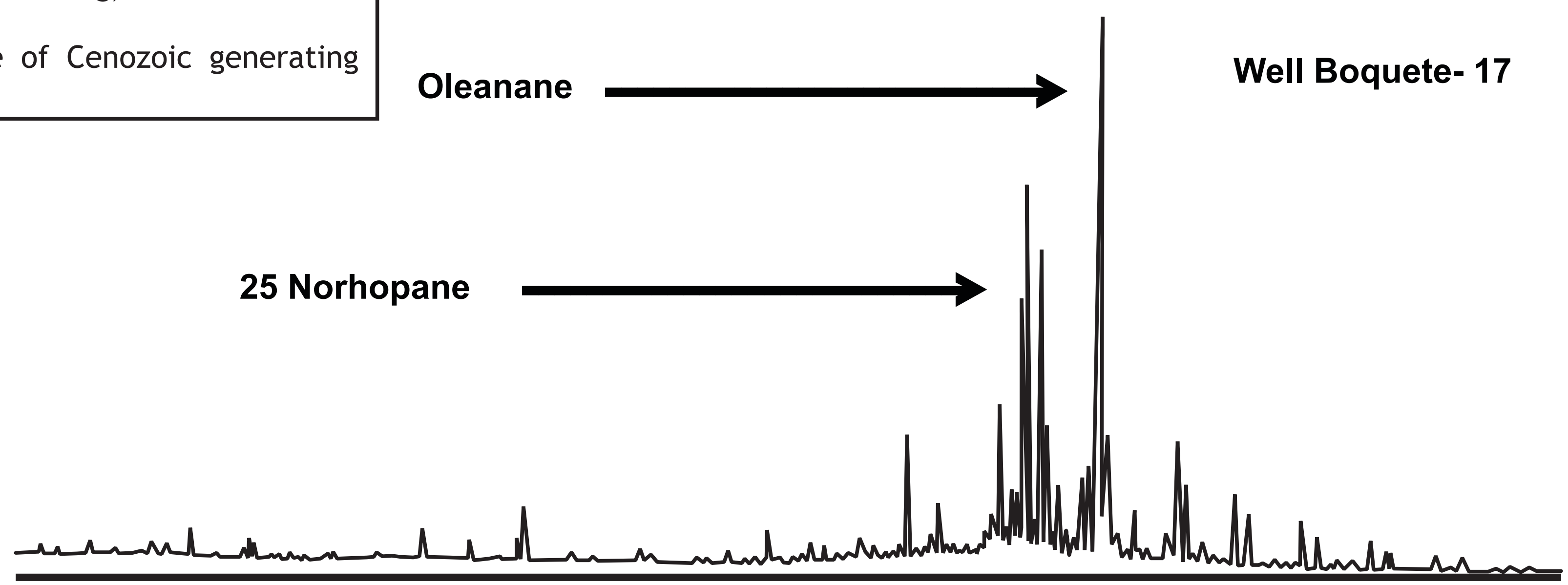
- The steranes ternary diagram (above) shows that the only sample in the basin has predominance of C29 steranes over C27 steranes, indicative of terrestrial organic matter input.

- In summary, the oils in the basin have Oleanane/C30 Hopane, C35/C34 Hopane, Pristane/Phytane and Pristane/nC17 ratio values supporting the presence of Cenozoic marine deltaic generating facies. They are very good quality oils with low sulfur content and high API gravities.

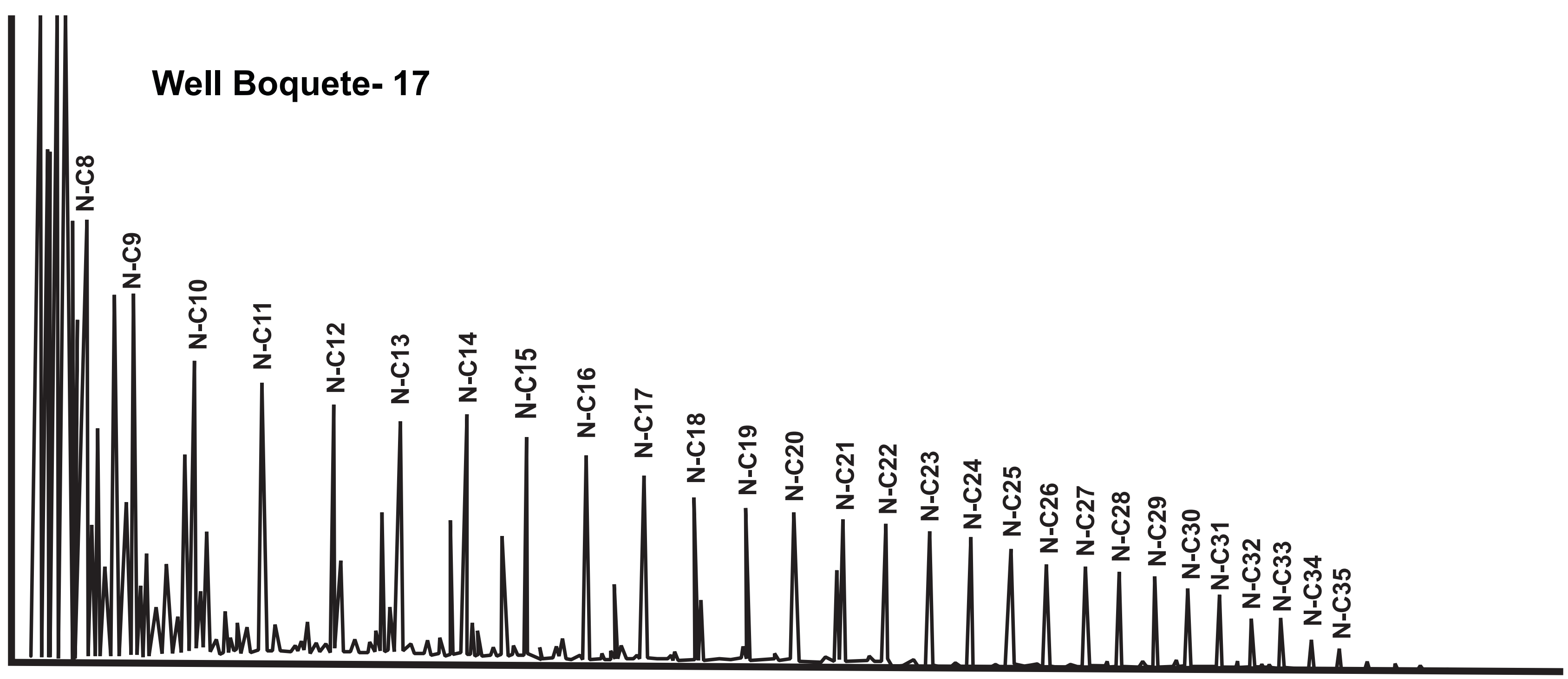
Chromatography

Chromatogram and fragmentogram of the Boquete-17 well, the presence of isoprenoids and normal alkanes along with biomarkers like 25 Norhopane suggests mixing of a biodegraded oil with fresh crude (refreshing).

Oleanane abundance is indicative of Cenozoic generating facies.



Fragmentogram m/z 191

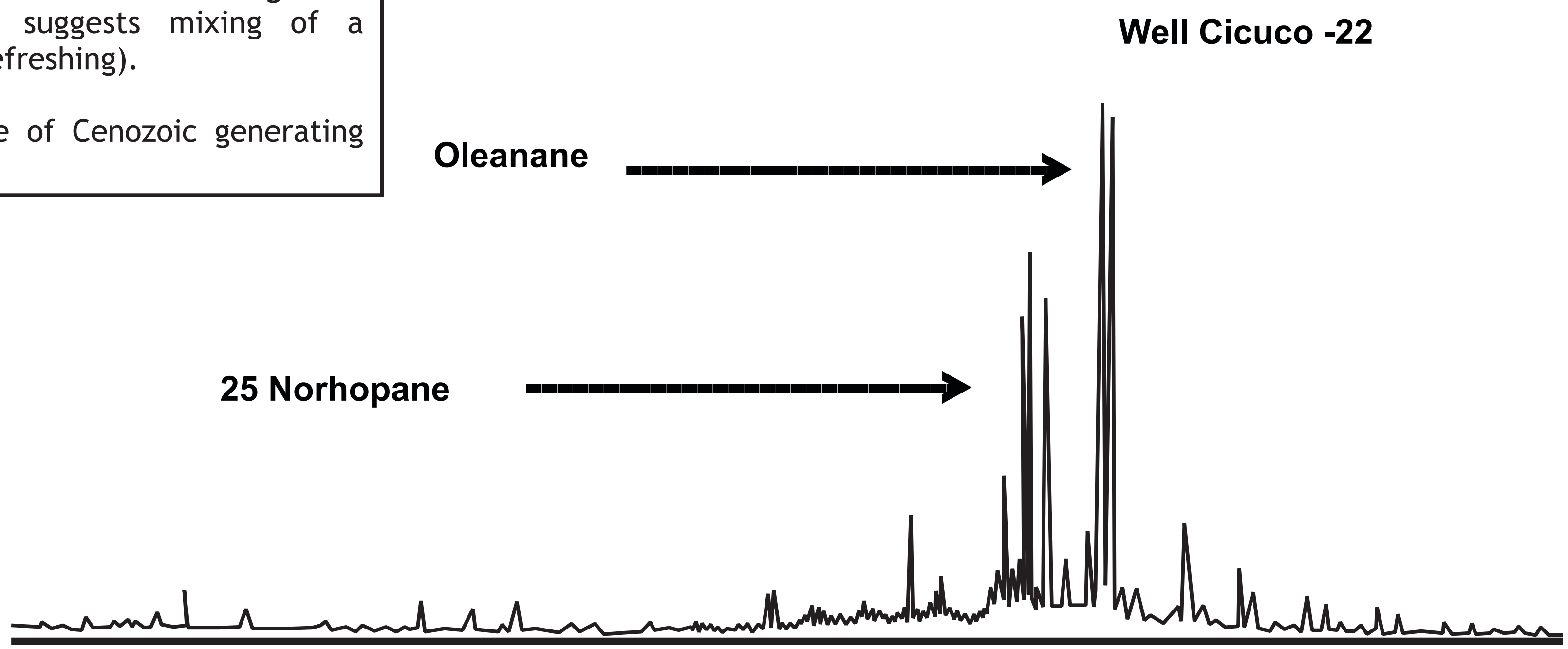


Chromatogram

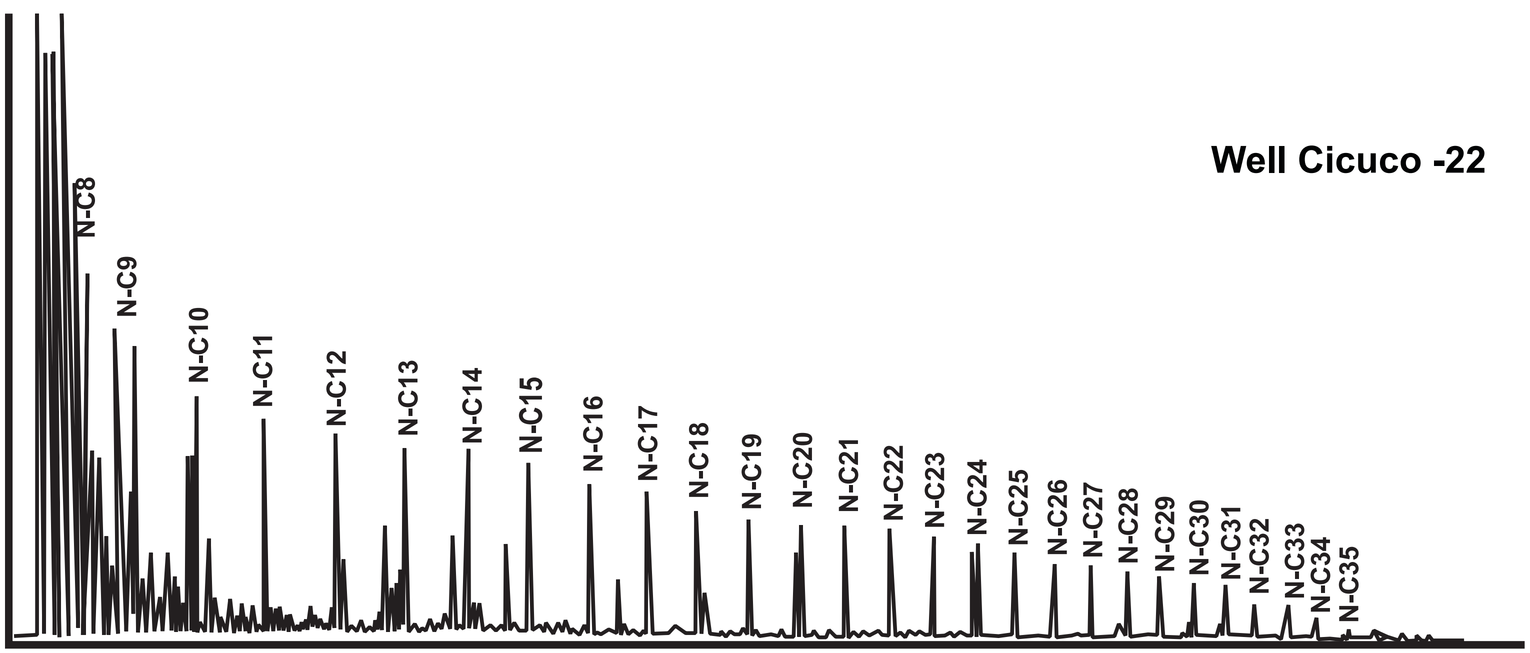
Chromatography

Chromatogram and fragmentogram of the Cicuco-22 well, the presence of isoprenoids and normal alkanes along with biomarkers like 25 Norhopane suggests mixing of a biodegraded oil with fresh crude (refreshing).

Oleanane abundance is indicative of Cenozoic generating facies.

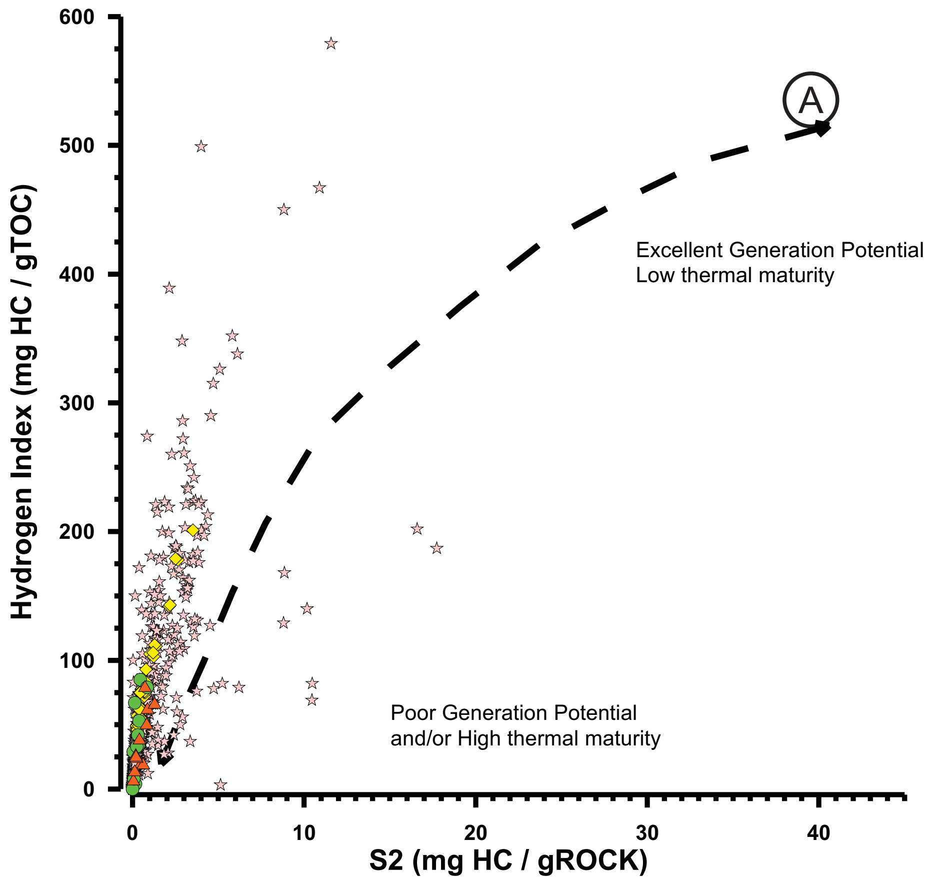


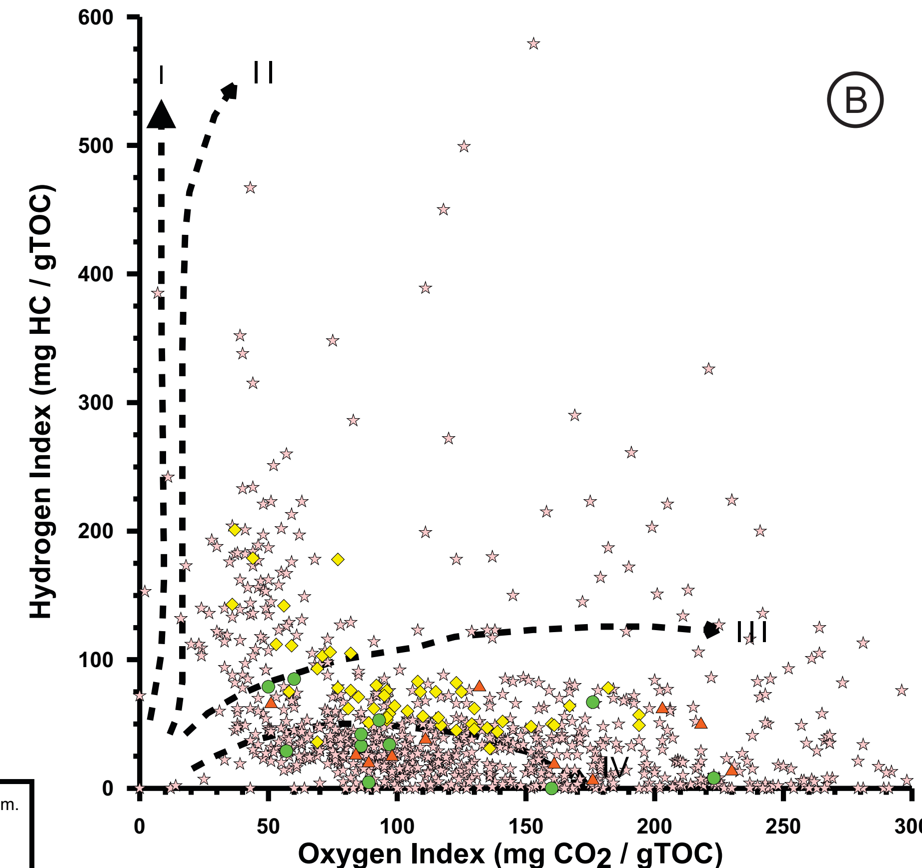
Fragmentogram m/z 191

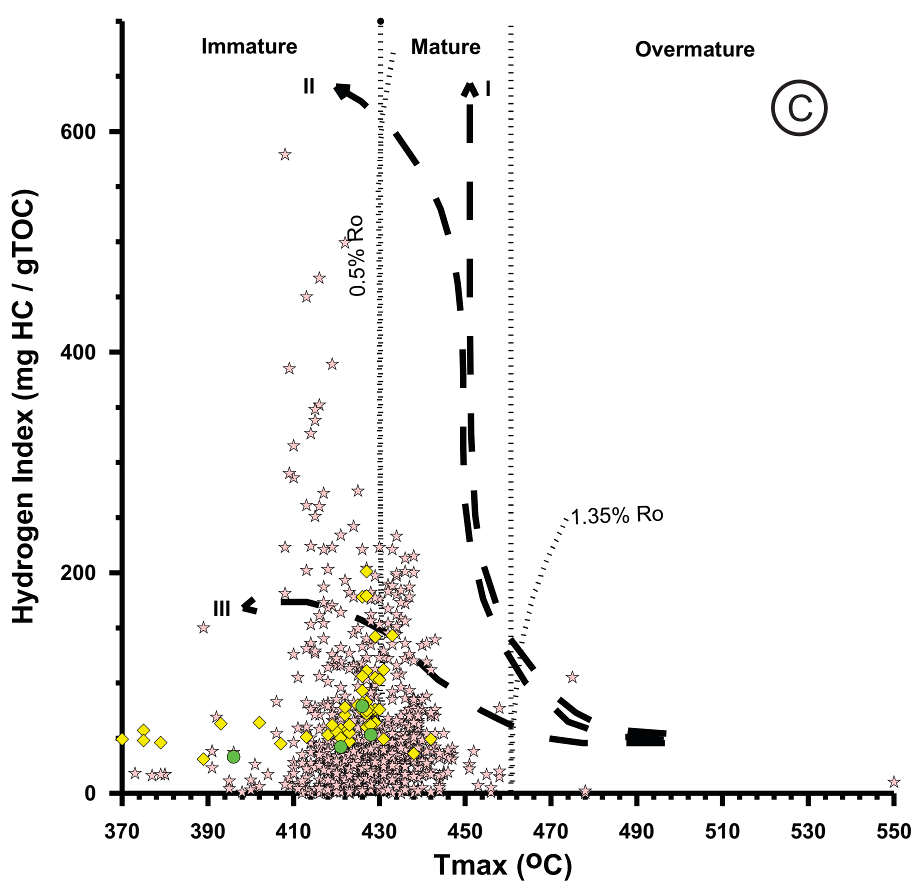


Chromatogram

Source Rock Characterization





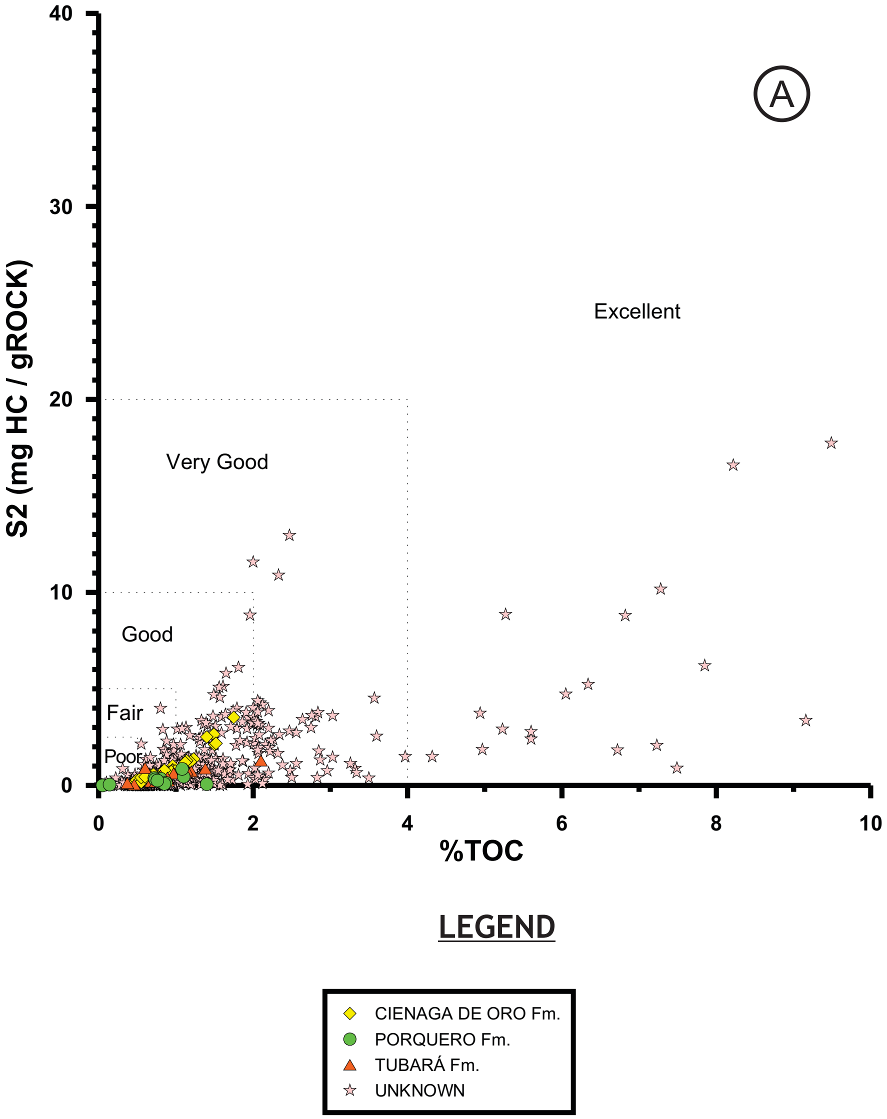


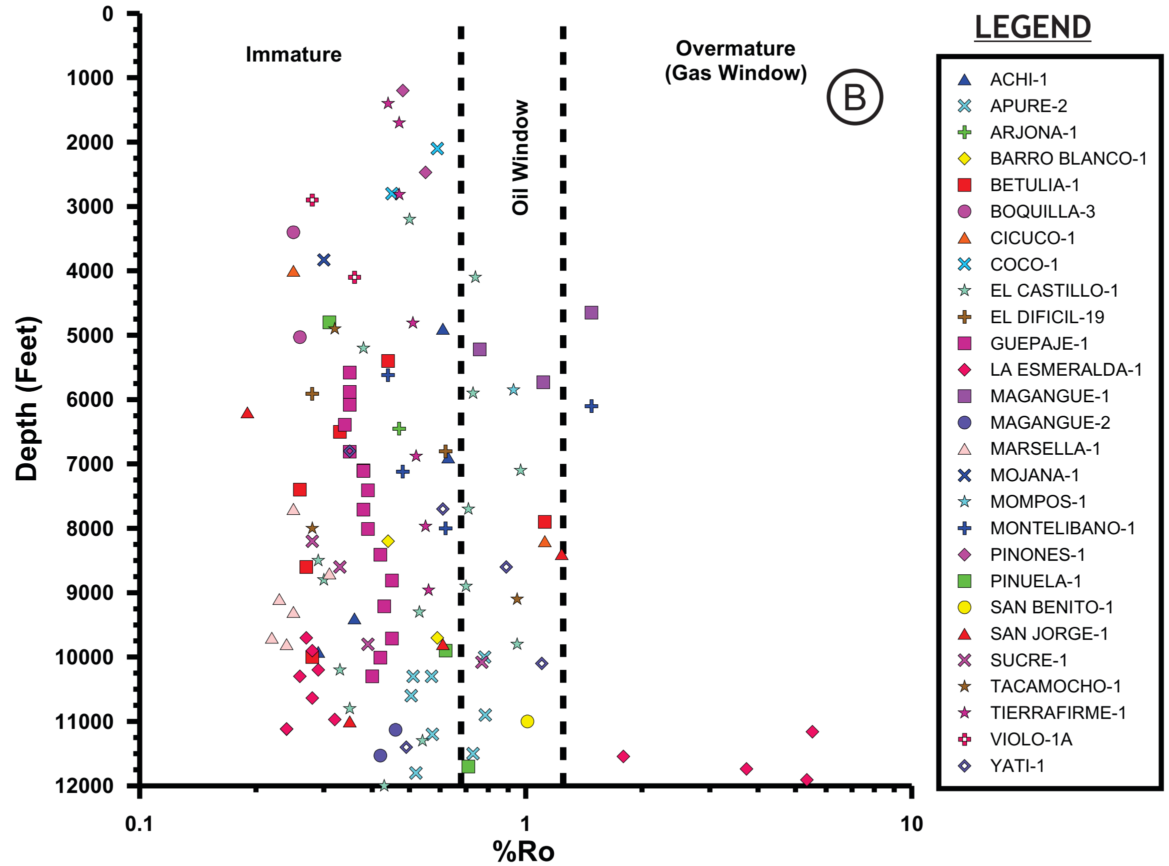
- The data obtained from pyrolysis of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Cenozoic Cienagá de Oro, Porquero and Tubará formations have poor generation potential (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock). There are samples with good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock) of unknown origin. (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cenozoic Ciénaga de Oro, Porquero and Tubará formations have type III gas-prone kerogen and type IV kerogen. There are also samples from unknown origin and the Ciénaga de Oro formation with more type II oil-prone characteristics. Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples have reached early maturity to oil generation peak conditions in the basi, with some samples of unknown origin at late maturity stages. The samples from the Ciénaga de Oro and Porquera formations have reached early maturity conditions in the basin (Figure C).

Source Rock Characterization



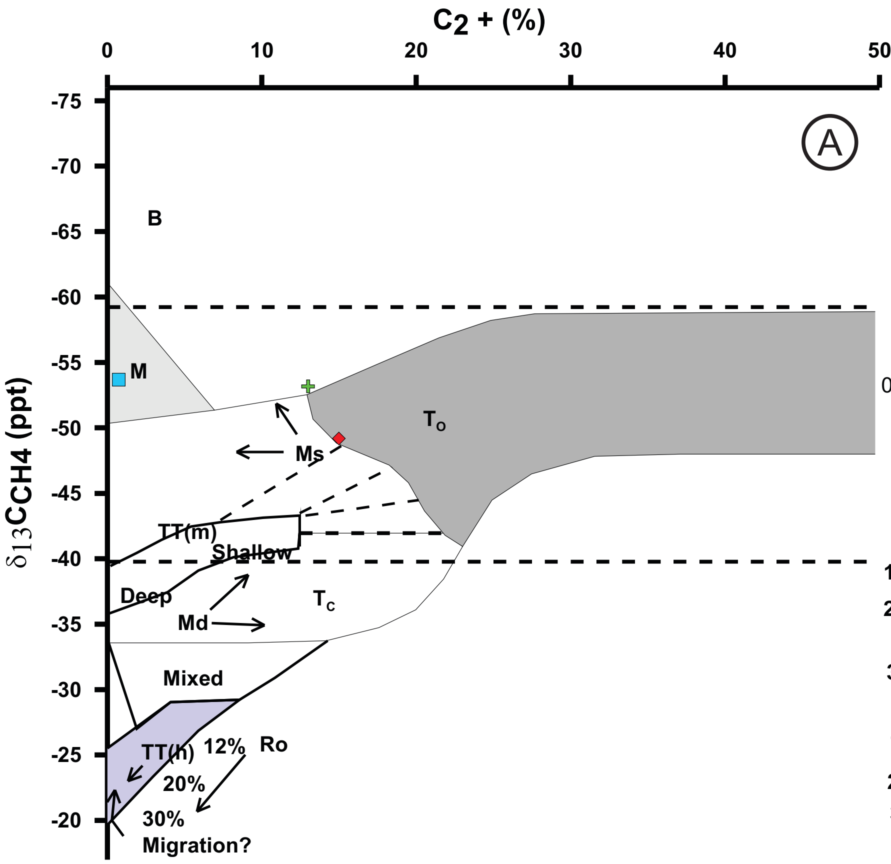


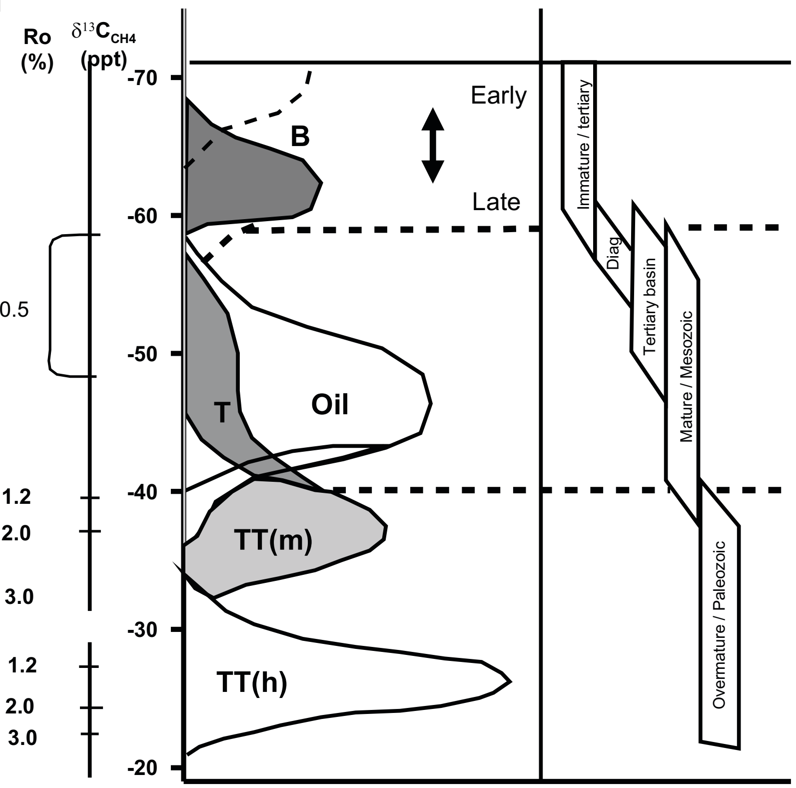
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from the Porquero and Tubará formations, with poor oil generation potential (S2 < 5 mg HC/g rock and %TOC < 1) and samples from the Ciénaga de Oro with fair oil generation potential (S2 up to 5 mg HC/g rock and % TOC up to 2). There are samples from unknown origin with better oil generation potential in the basin (Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence is in most wells immature or close to early maturity in the basin. The wells with samples in the oil generation window and overmature values explain the high API gravities of the oils found in the basin (Figure B).

-In summary, the best source rock at the basin, although without good source rock characteristics, seems to be the Ciénaga de Oro Formation. However samples from unknown origin have the best generation potential in the basin, and might be the best generatin facies of the hydrocarbons found. Maturity data indicates that the sedimentary sequence is mature enough to generate high quality oils in the basin.

Gas Characterization

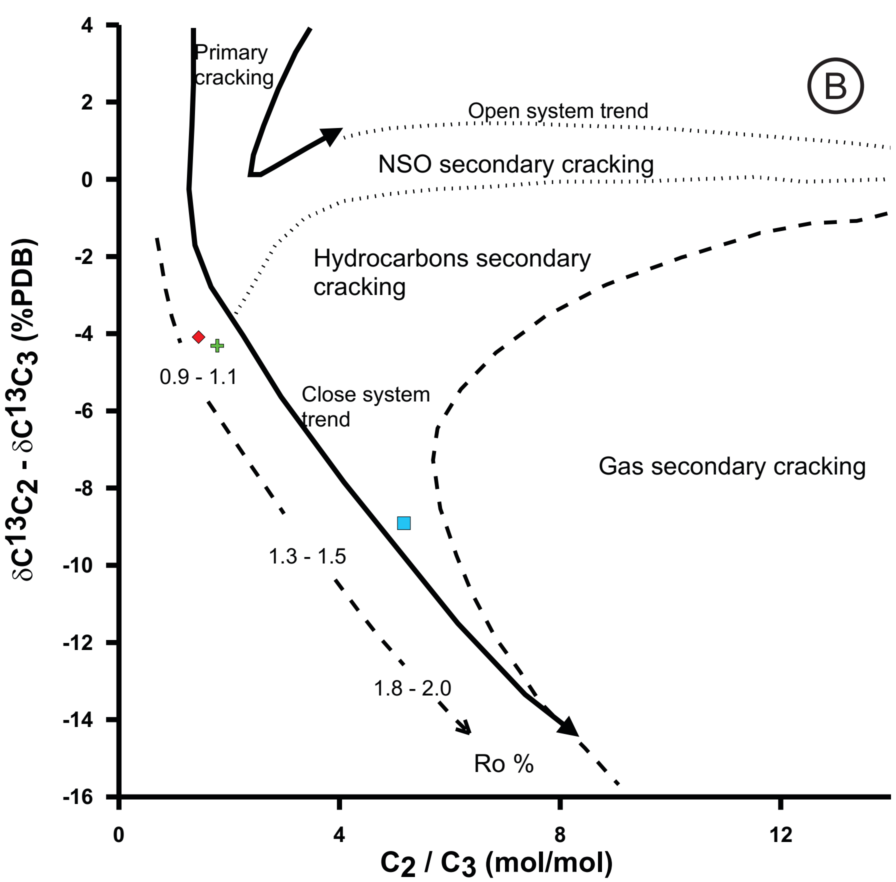




B	Biogenic gas
T	Crude oil gases
To/Tc	Crude and condensate gases
TT(m)	Dry gases associated to sapropelic organic matter.
TT(h)	Gases associated to humic organic matter
M	Mixed gases
Md	Deep Migration
Ms	Shallow Migration

LEGEND

- BOQUETE-3
- CICUCO 15
- GUEPAJE-1

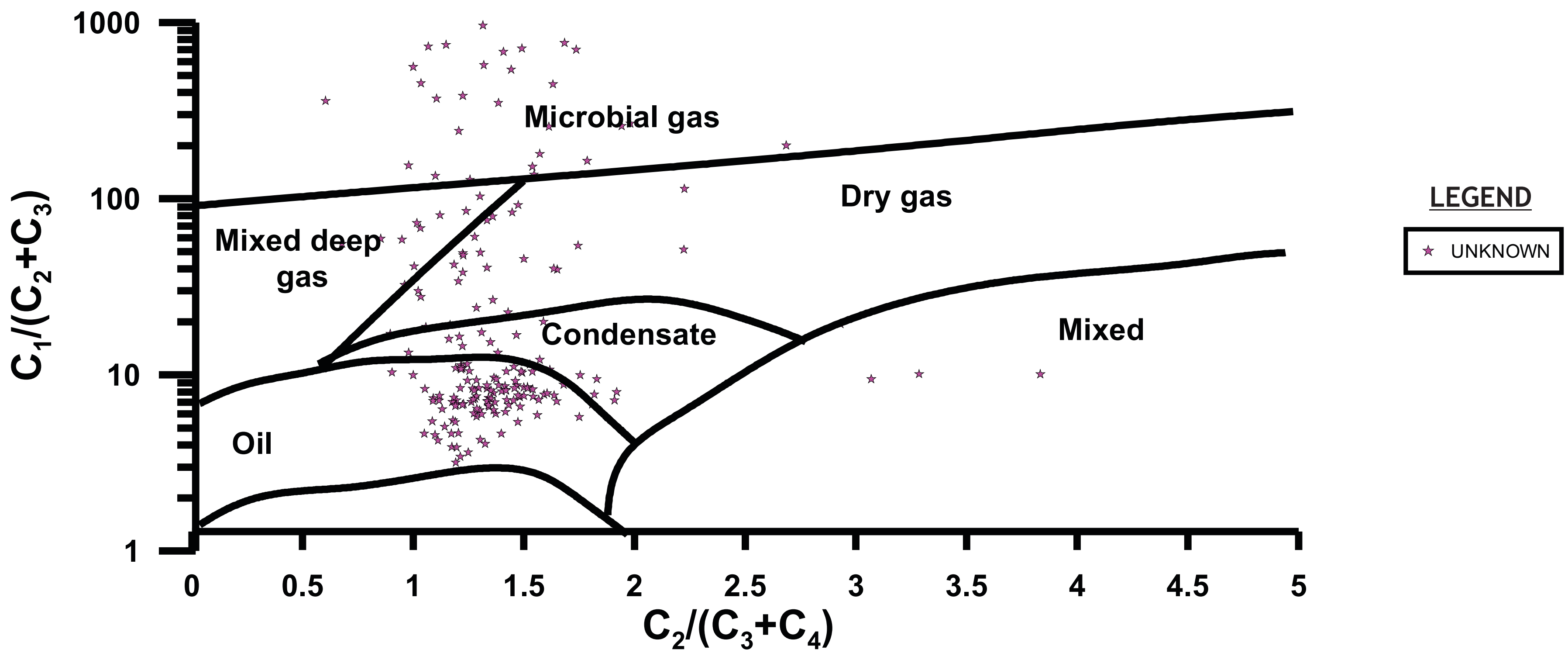


- The samples analized in the Lower Magdalena Valley Basin correspond to gases from crude oils.

- The C2+(%) vs d13C Ch4 (ppt) diagram (Schoell, 1983), suggests that the Boquete-3 and Cicuco-15 well samples correspond to thermogenic gases associated to the oils found in the basin, but with different levels of thermal evolution, while the Guepaje-1 sample could correspond to mixing of gases of different origin.

- The C2/C3 vs d13C C2 - d13C C3 diagram, suggest that the gas samples analized were originated by primary cracking. With increasing cracking of the Guepaje-1 sample.

Surface Geochemistry



Compositional data from surface geochemistry samples indicate that there are hydrocarbons of thermogenic and biogenic origin at the basin, formed mainly during oil and gas generation window indicative of a variable maturity level of the sources at the basin.

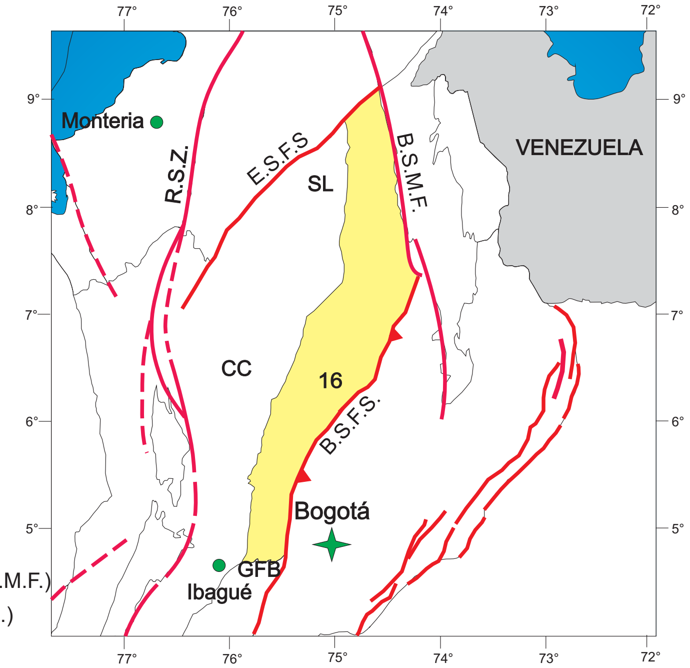
The microbial gas found in the basin, characterized by its very high content of methane, could be related to bacterial degradation, considering the fact that it has similar C2/(C3+C4)ratios regarding the thermogenic gases.

MIDDLE MAGDALENA VALLEY BASIN

Generalities
Wells and Seeps
Crude Oil Quality
Depositional Environment
Chromatography
Source Rock Characterization
Source Rock Quality and Maturity Maps
Gas Characterization
Surface Geochemistry

Generalities

MIDDLE MAGDALENA VALLEY BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

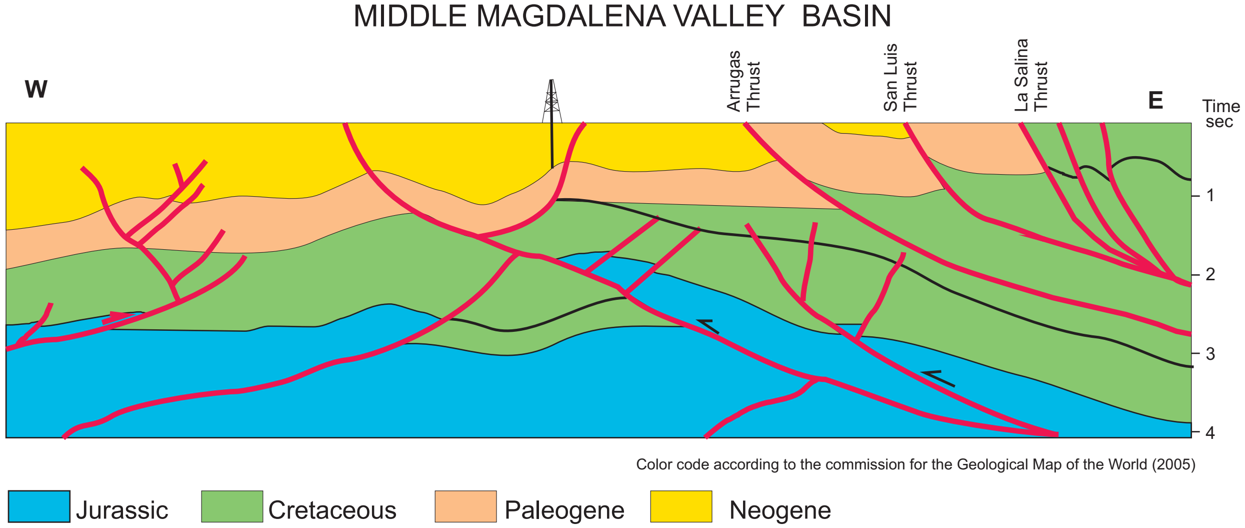
North: Espiritú Santo fault system (E.S.F.S)
Northeast: Bucaramanga-Santa Marta fault system (B.S.M.F.)
Southeast: Bituima and La Salina Fault System (B.S.F.S.)
South: Girardot fold beld (GFB)
West: Onlap of Neogene sediments over the Serranía de San Lucas (SL) and Central Cordillera (CC) basement

From Barrero et al., 2007

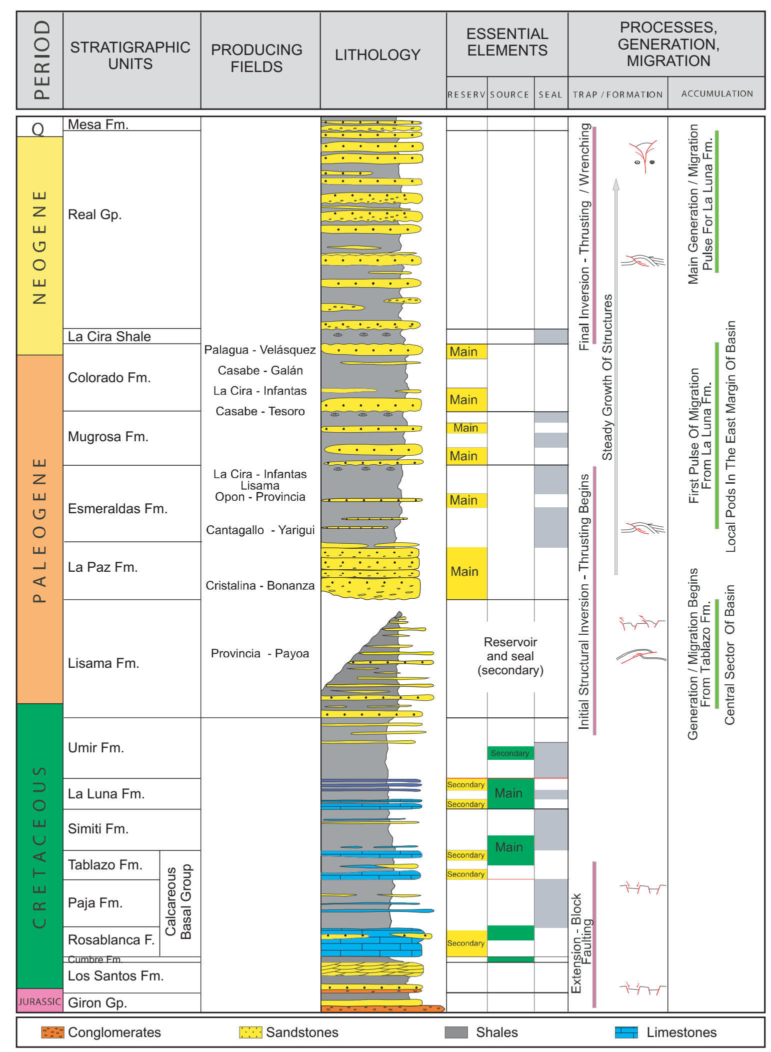
The source rock geochemical information interpreted for the Middle Magdalena Valley Basin includes %TOC and Rock-Eval Pyrolysis data from 646 samples taken in 23 wells; additionally 636 organic petrography samples from 30 wells were interpreted.

Crude oil and extracts information from 402 bulk analysis samples, 376 liquid chromatography samples, 294 gas chromatography samples, 150 biomarker samples,195 isotopes samples and 194 surface geochemistry samples were also interpreted.

SCHEMATIC CROSS SECTION
MIDDLE MAGDALENA VALLEY BASIN

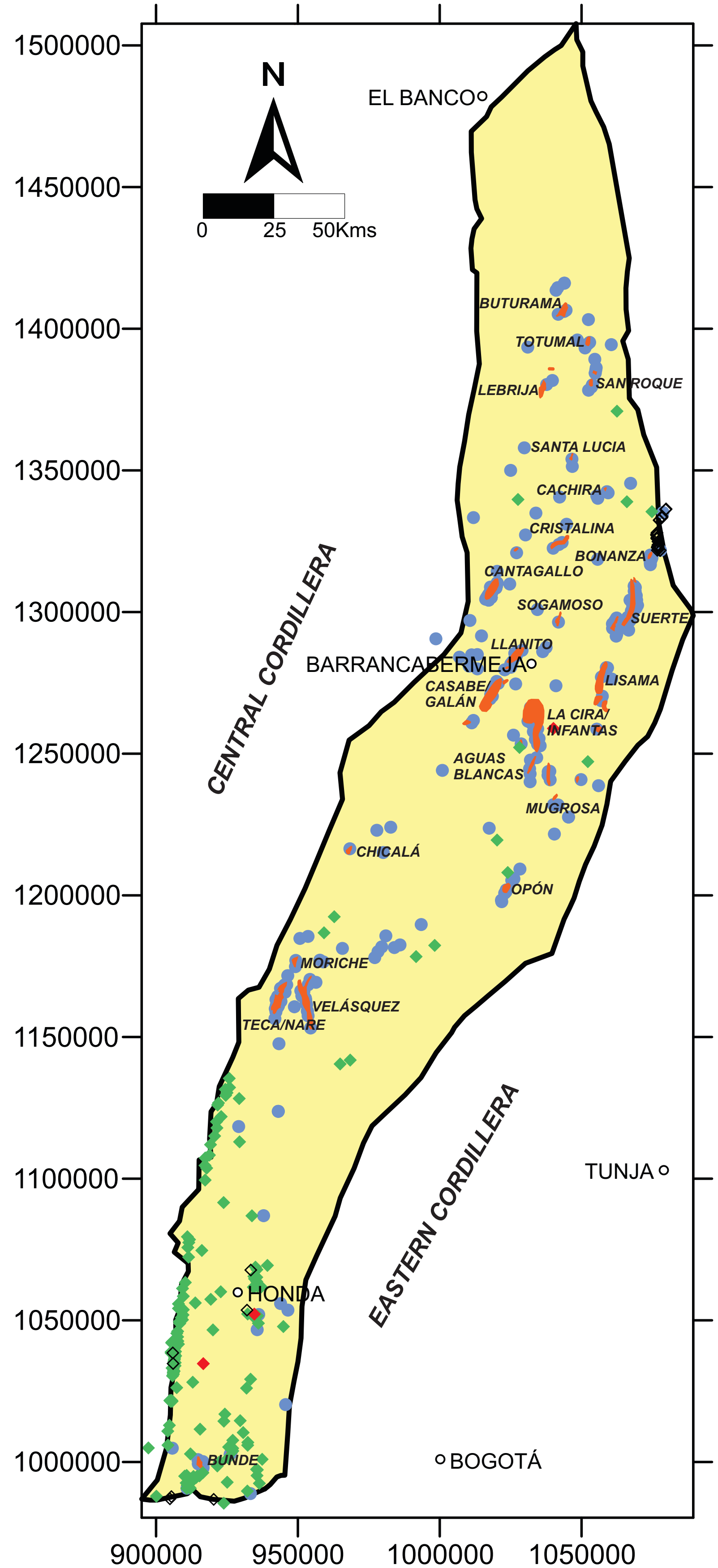


From Barrero et al., 2007



From Barrero et al., 2007

Wells and Seeps



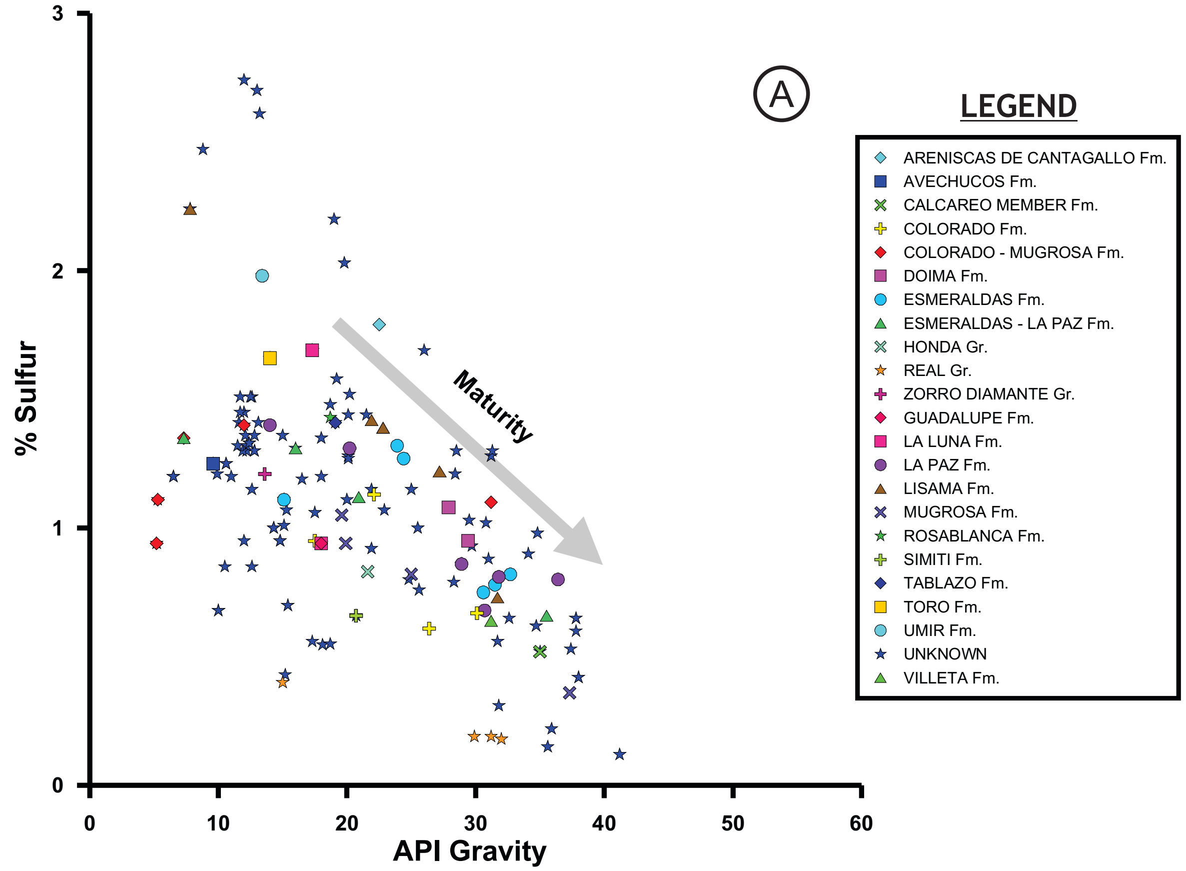
The number of wells and/or surface locations with geochemical information in the Middle Magdalena Valley Basin is 320.

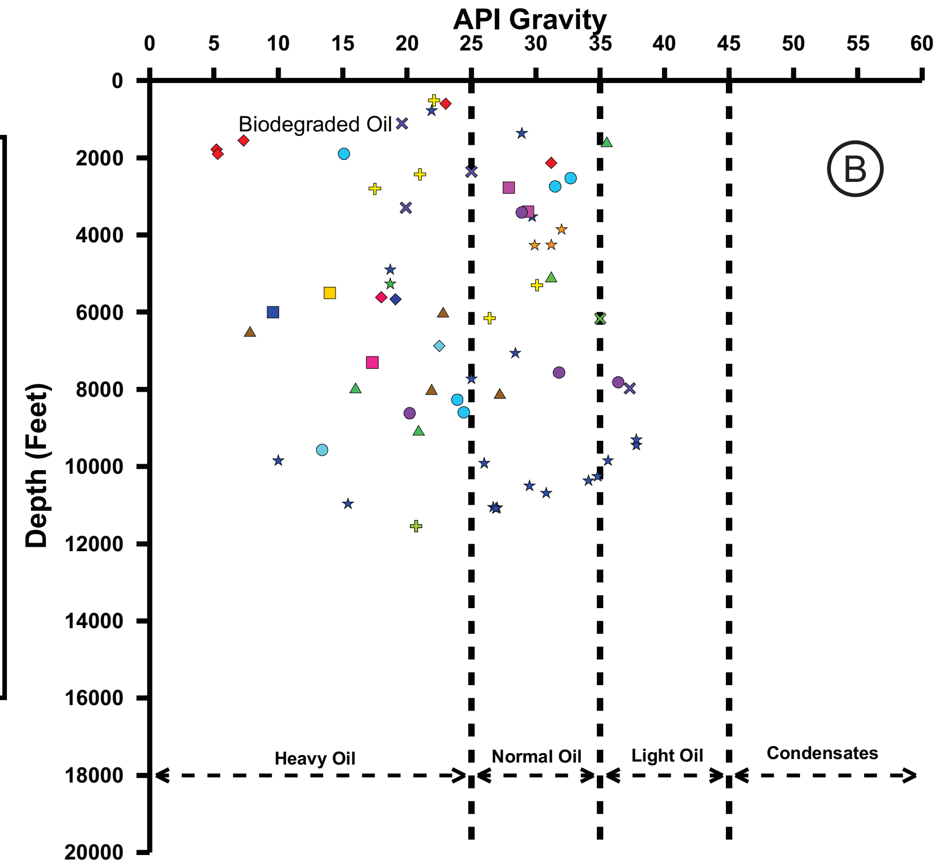
Oilseeps are located widespread in the basin.

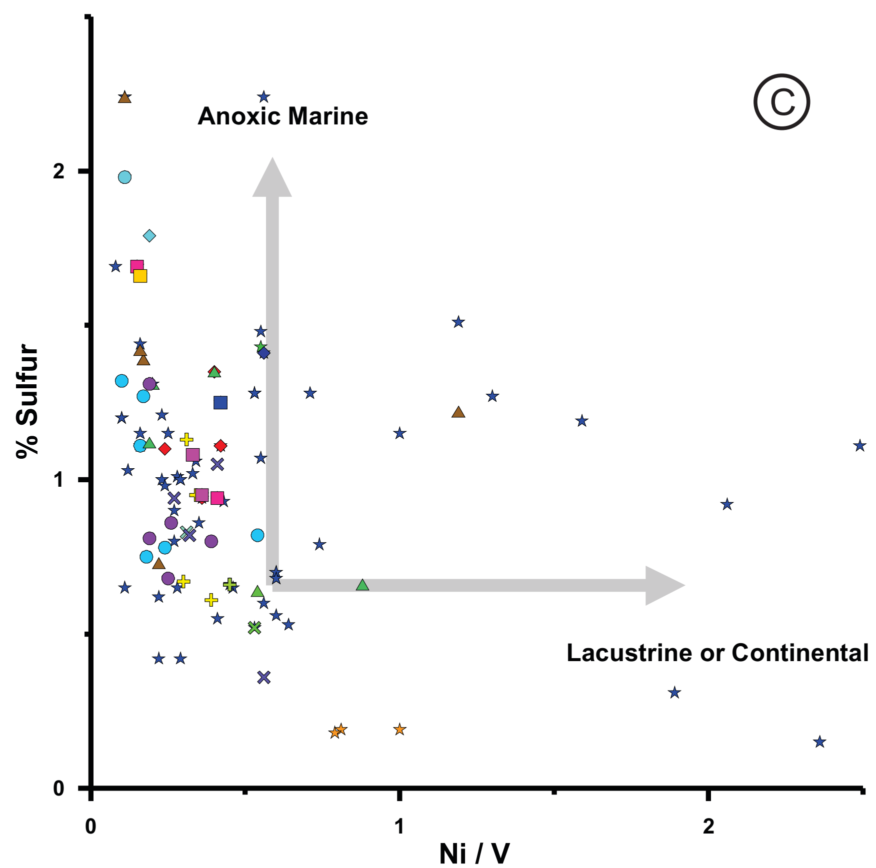
- Oil and gas fields
- Wells with geochemical information
- Oil seeps
- Gas seeps
- Undetermined seeps
- Cities/Towns

Map datum: Magna Sirgas
Coord. origin: Bogotá

Crude Oil Quality





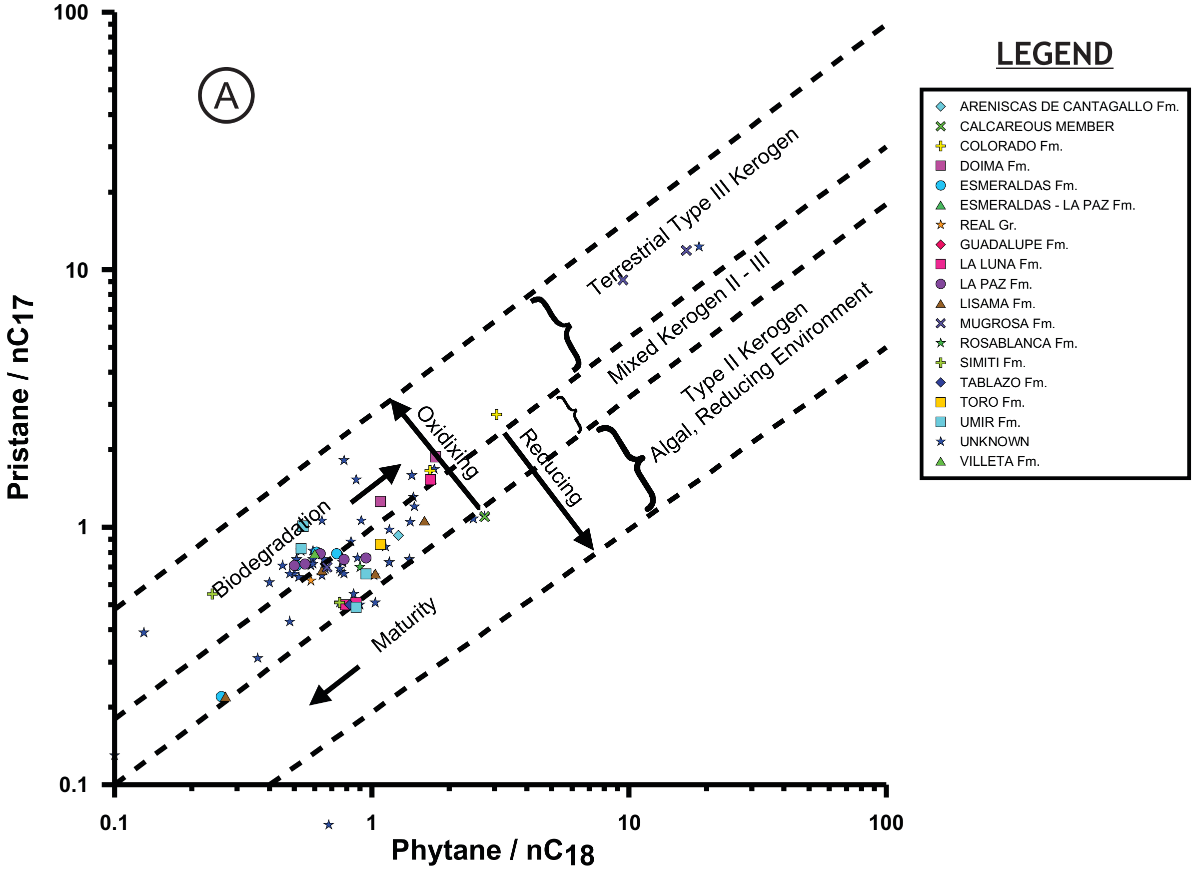


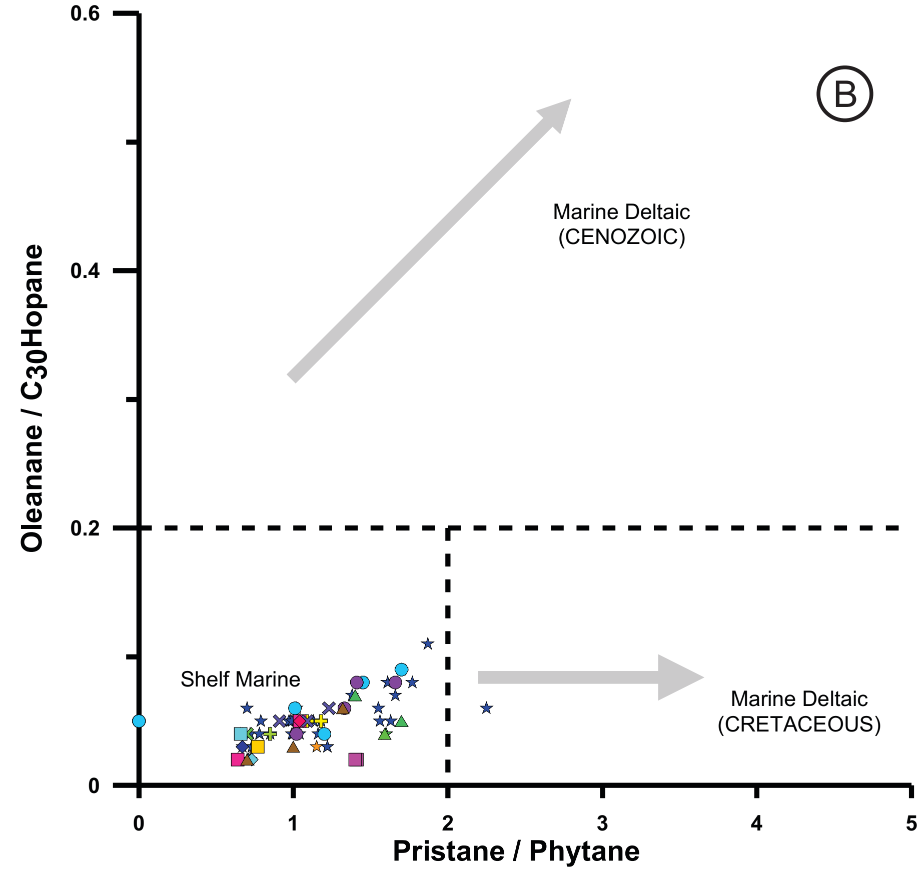
- Heavy to light oils with API gravities ranging from 5° to 40° and sulfur content between 0 and 3% are present in the basin. There is no straight relationship between sulfur and API gravity, but there is a progressive decrease in sulfur content as API gravity increases. This suggests that in the basin there are oils with different thermal maturities,the more mature have higher API gravity and lower sulfur content; but there are also crudes that having similar API gravities have different sulfur contents, which might indicate biodegradation, increasing sulfur content, and/or different source rocks, considering that oils sourced from shales usually have lower sulfur content than oils from carbonates (Figure A).

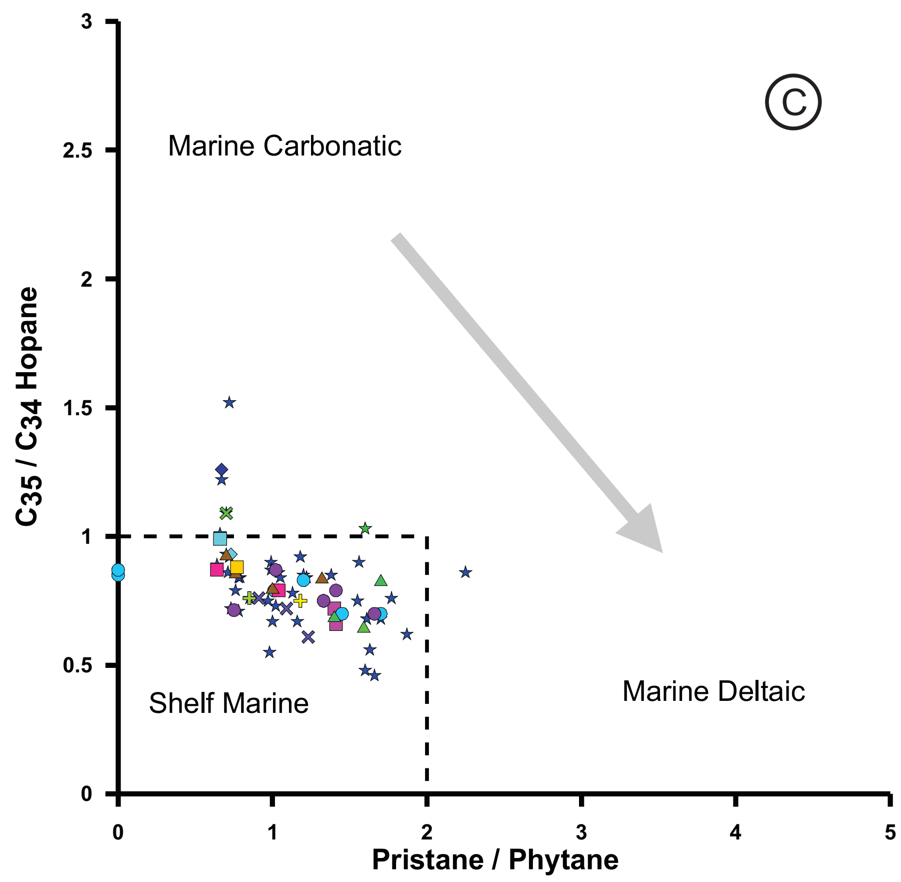
- There is no direct relationship between depth and crude oil quality, indicating that similar quality oils can be found at different stratigraphic levels, probably related to vertical migration in faulted reservoirs or regional faults. But additionally there is the fact that different API gravity oils can be found at similar depths, reflecting different preservation (biodegradation) and/or thermal maturities (Figure B).

- The sulfur content of most crude oils is lower than 1.5 %, and its Ni/V ratio below 0.5, suggesting that they are produced from rocks deposited in a marine suboxic environment with low terrigenous organic matter input (Figure C).There are some samples with high Ni/V indicating high terrigenous input.

Depositional Environments





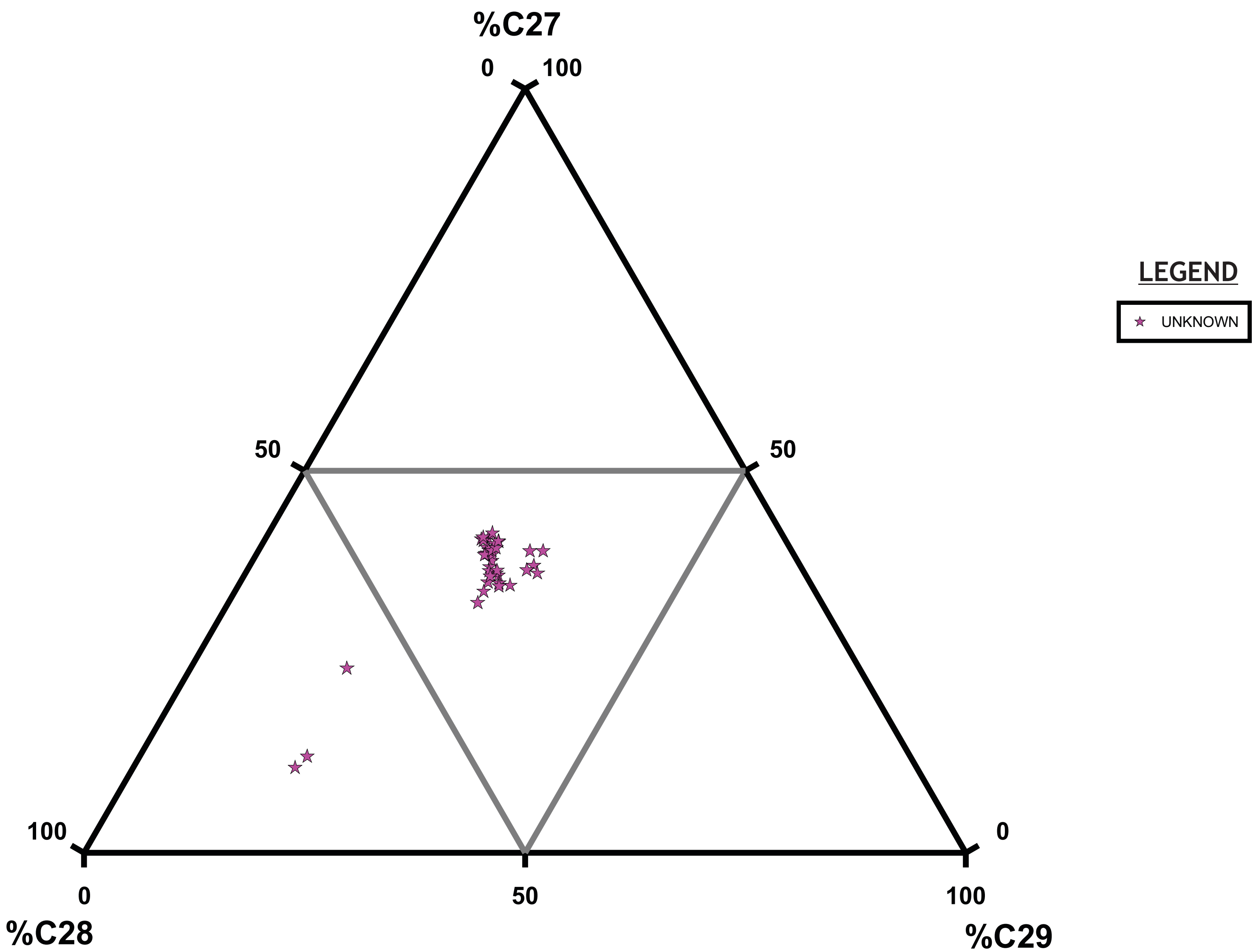


- The Phytane/nC18 vs Pristane/nC17 graph indicates that most of the oils have origin from mixed kerogen suggesting a source with terrestrial and marine organic matter input (Type II and III kerogens) deposited in more reducing conditions. There are also several oils with more type III kerogen characteristics, indicating more terrestrial organic matter input and oxidizing conditions of the source rock (Figure A). The data also suggests variable preservation of the crude oils (biodegradation).

- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that most of the oils have low oleanane index values (<0.2) and Pr/Ph values (<2) which indicates that these oils are generated from source rocks deposited in shelf marine environments. There is one sample with low oleanane index values but high Pr/Ph (>2) indicating that this oil was generated from source rocks deposited in marine deltaic environments. The oleanane index has been also used as an age indicator of the source rock, with high oleanane values for oils generated in Cenozoic rocks and low oleanane values in oils from older rocks (Figure B).

- The Pristane/Phytane vs C35/C34 Hopane (Homohopane index) graph shows that most oil samples have Pr/Ph values below 2 and C35/C34 Hopane below 1, indicating that these oils were generated from siliciclastic rocks deposited in a shelf marine environment. Additionally there is one sample with low homohopane index but higher Pr/Ph values (>2) indicative of siliciclastic rocks deposited in marine deltaic environments (Figure C).

Depositional Environments



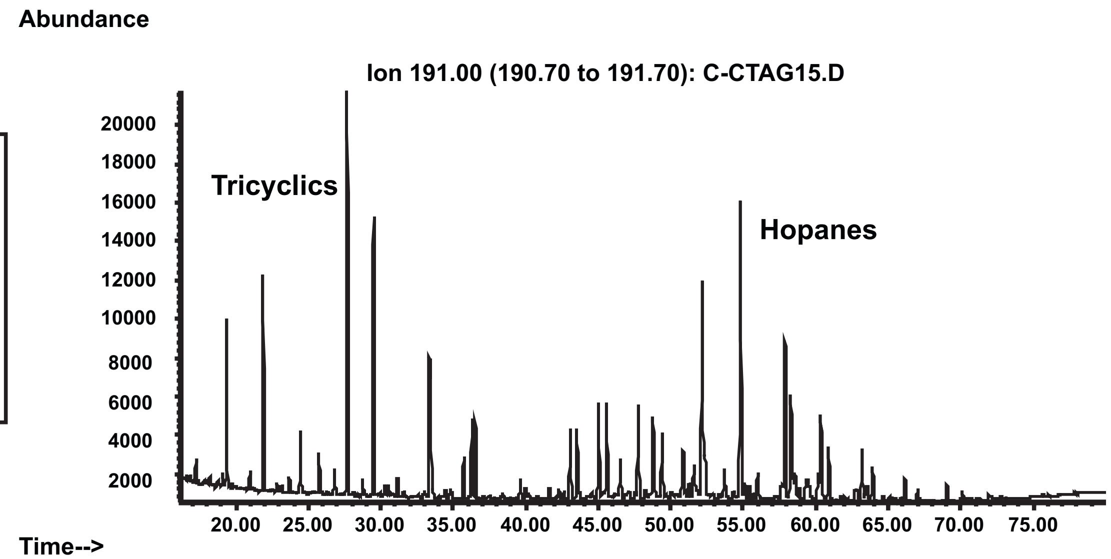
The steranes ternary diagram (above) shows that C27 steranes predominate over C29 steranes in the oil samples , indicating higher presence of marine organic matter than terrestrial organic matter in the source rocks.

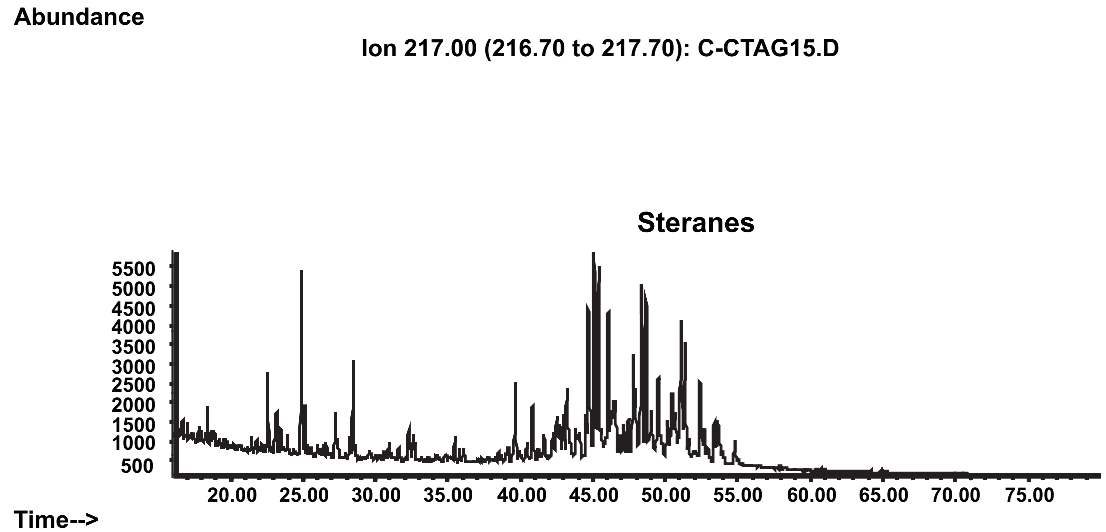
- In summary the oils in the basin correlate with generating facies deposited during the Cretaceous in siliciclastic marine shelf environments, with variable terrestrial organic matter input. The Cretaceous sedimentary sequence in the Middle Magdalena Valley includes units like the Paja, Tablazo,Simití, La Luna and Umir formations that could match the generating facies indicated by the crude oils in the basin.

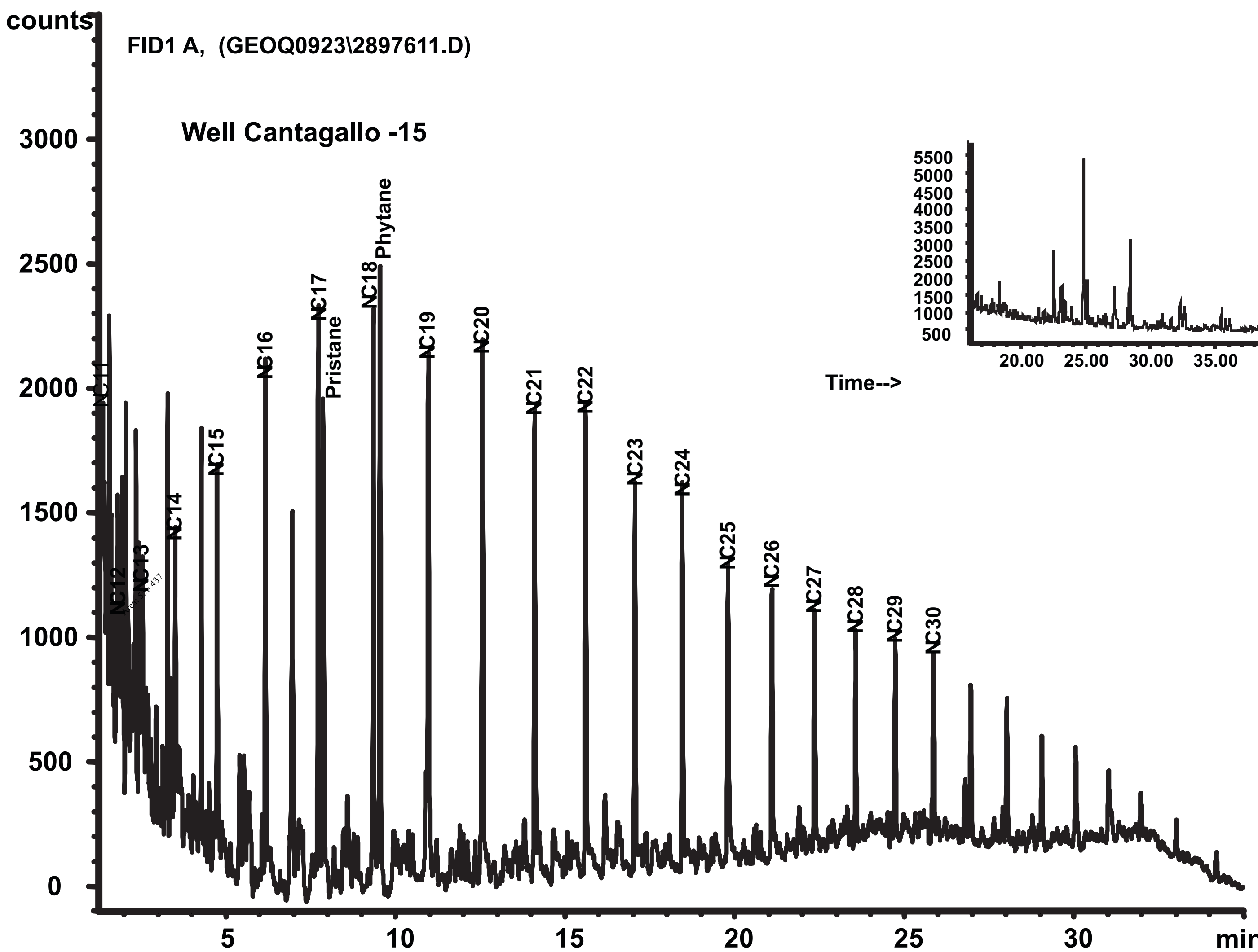
Chromatography

There are crude oils correlatable with clay-poor (carbonatic?) marine facies, like those of the Cantagallo Field, which have low to medium molecular weight paraffins and Pristane/Phytane ratio < 1.0.

This crude shows predominance of tricyclics over hopanes indicating high thermal maturity.







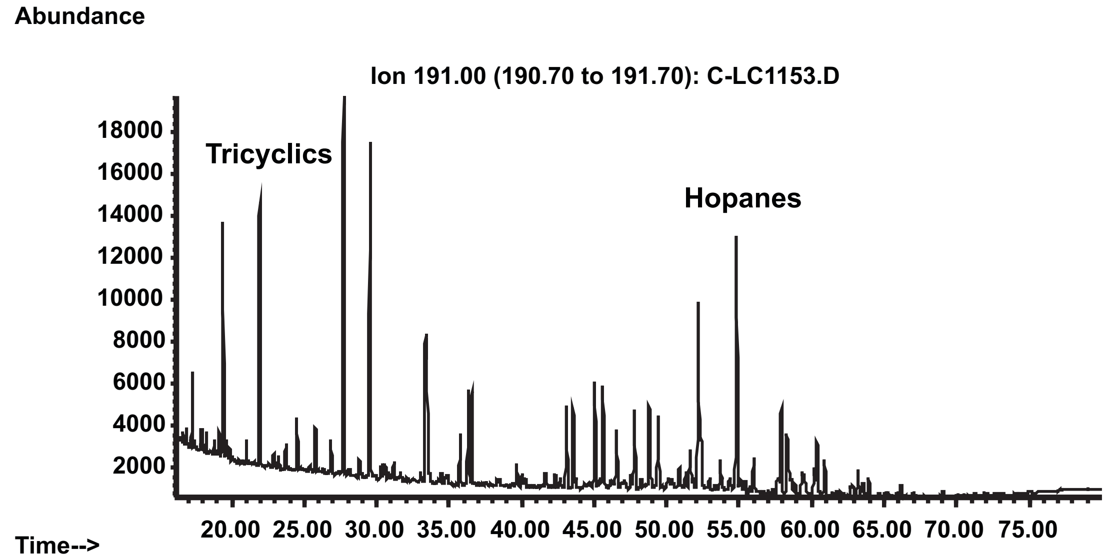
Chromatogram

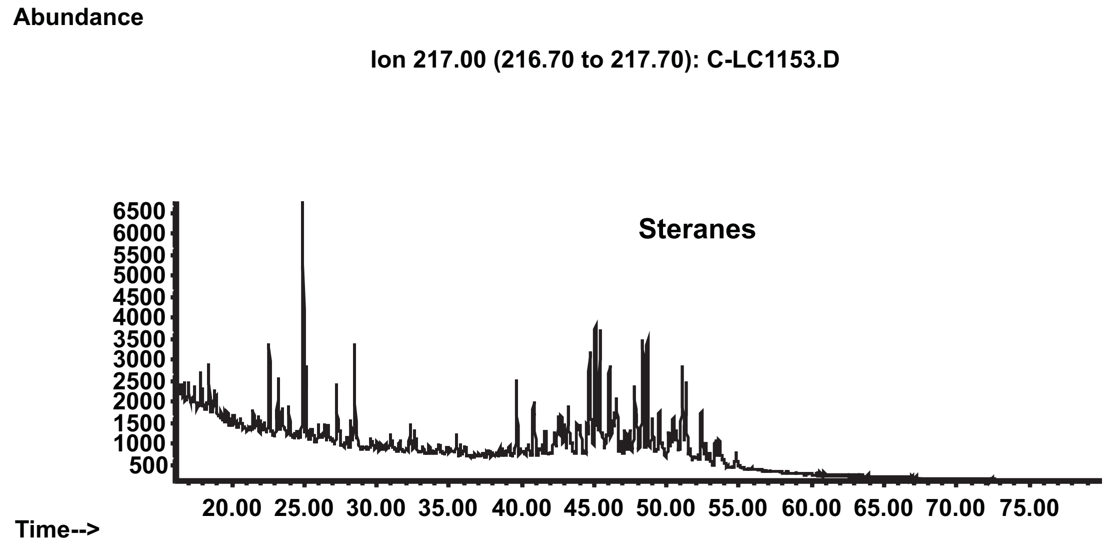
Chromatography

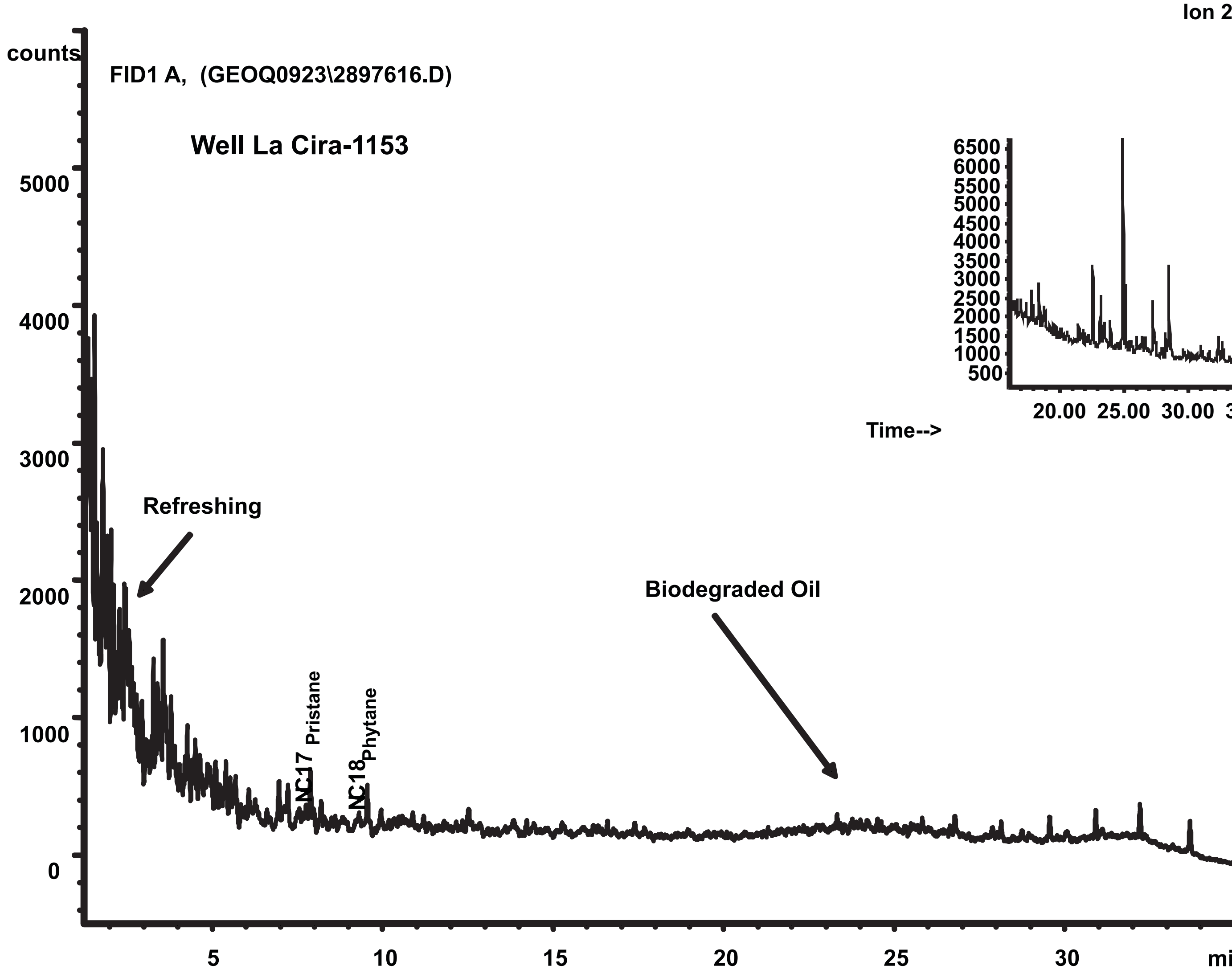
In the central part of the basin (La Cira - Infantas Field), exist crude oils affected by biodegradation processes that have removed the normal alkanes.

In some wells like La Cira 1153, are observed freshing with very light oils added during a second generation pulse.

This crude shows predominance of tricyclics over hopanes indicating high thermal maturity.

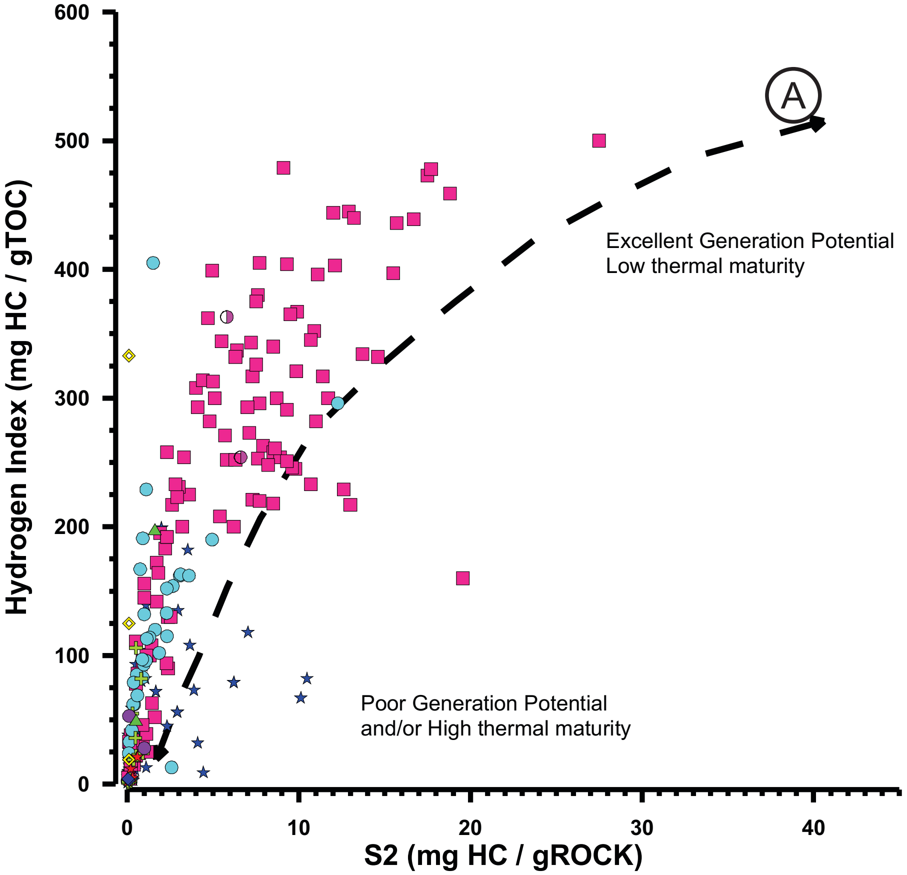


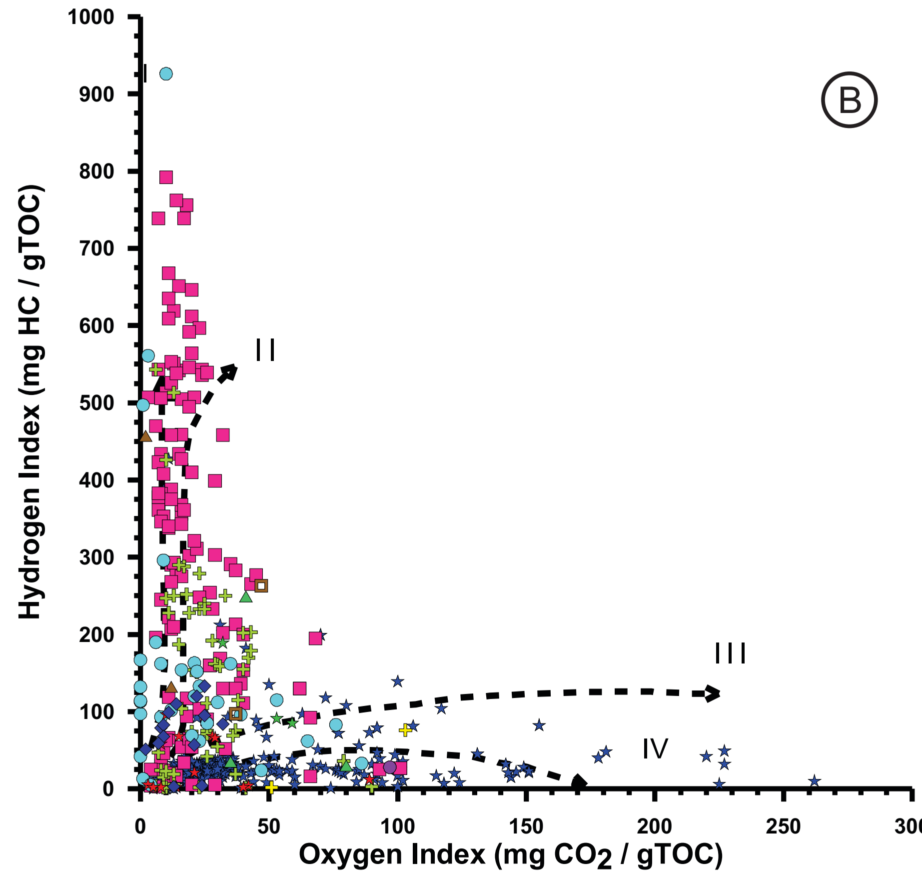


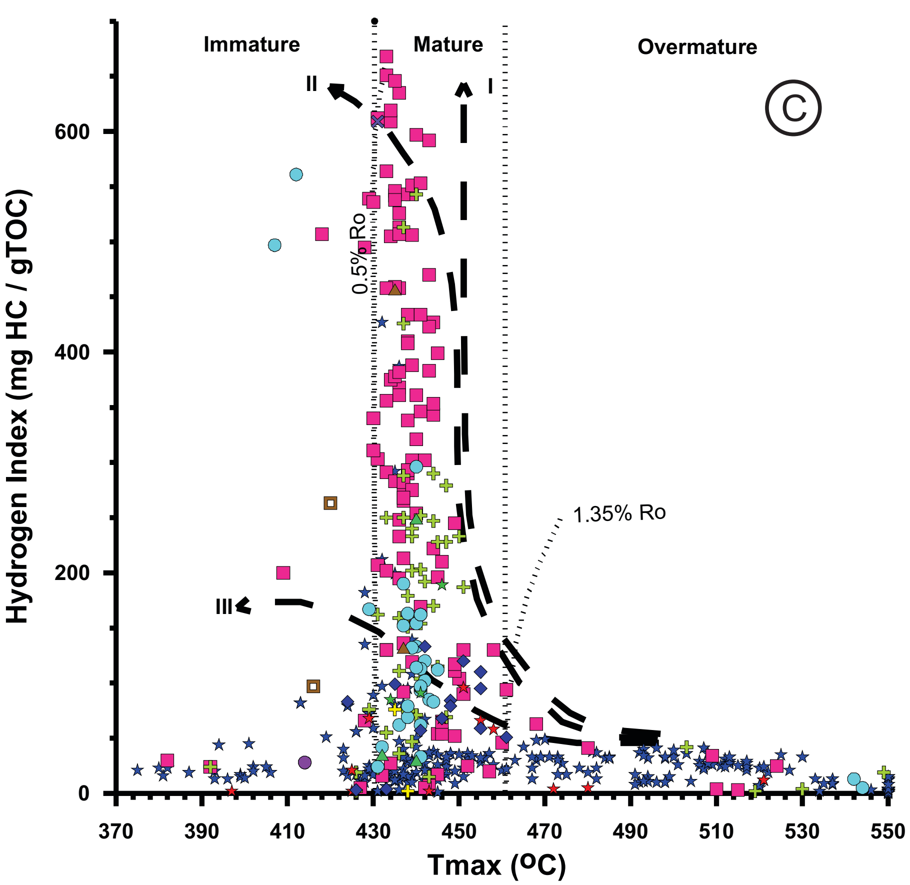


Chromatogram

Source Rock Characterization





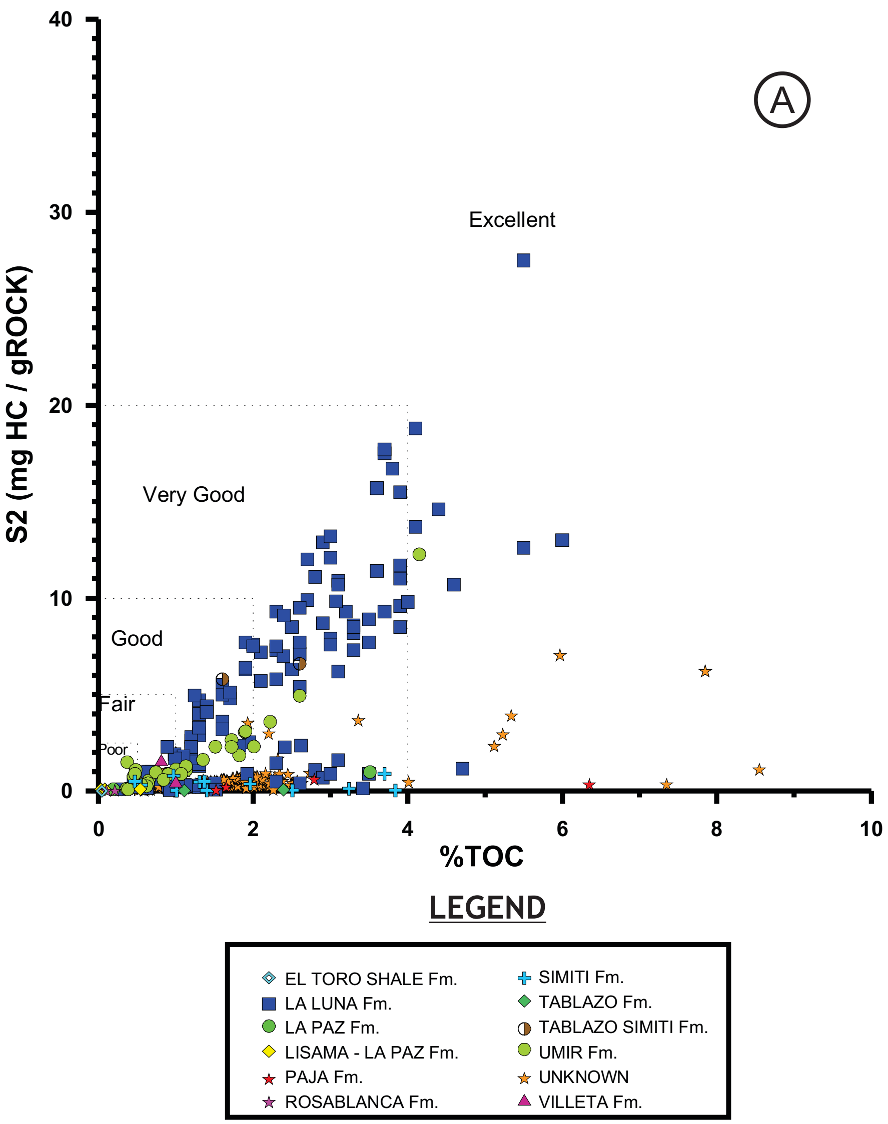


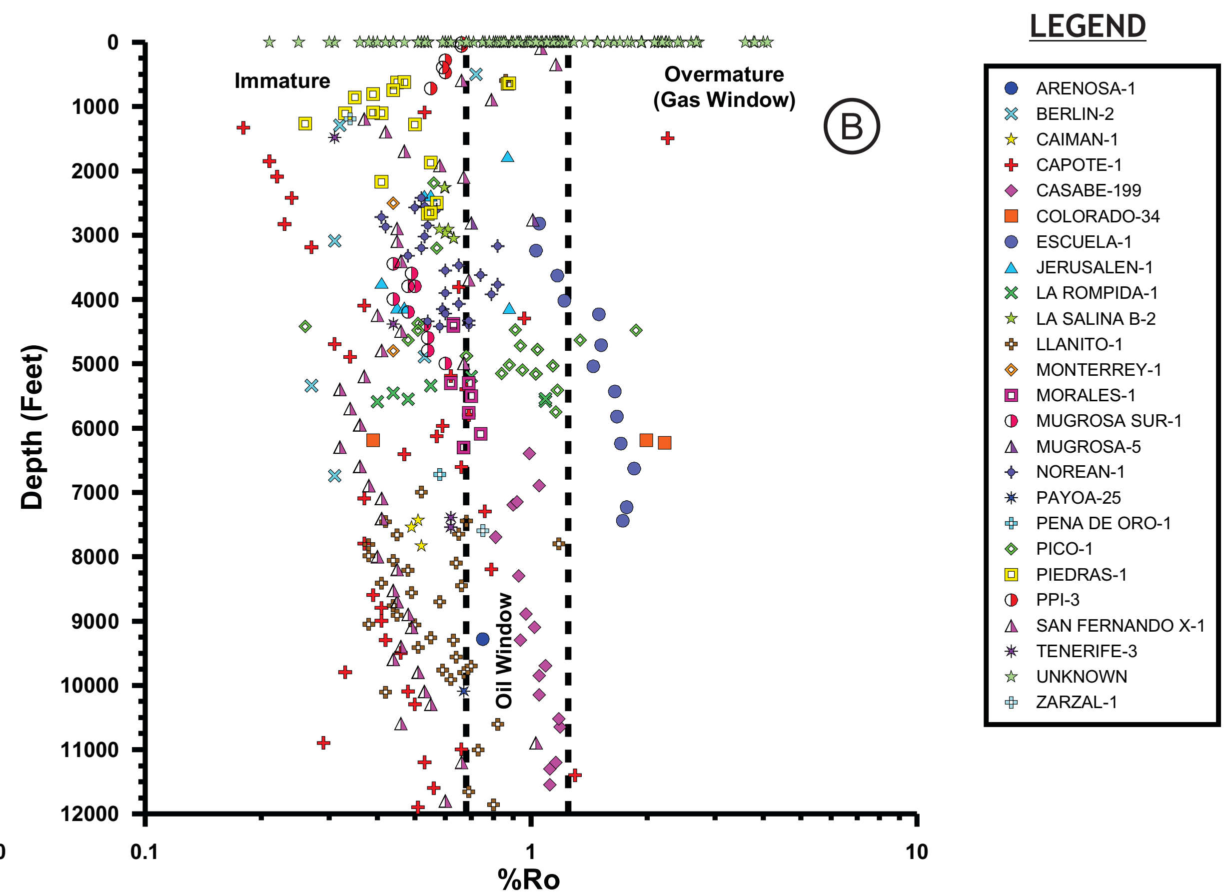
- The data obtained from pyrolysis Rock-Eval of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Cretaceous La Luna and Umir formations have good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock), and that samples from Cretaceous Calcareous Basal Group (Rosablanca, Paja and Tablazo formations), The Simití Formation and the Cenozoic Lisama, La Paz, Esmeraldas, Mugrosa and Colorado formations have poor generation potential (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock). Taking into account that the Cretaceous units are deeply buried in the basin, the poor generation values obtained from some samples could reflect the depletion effect caused by the high thermal maturity of these rocks (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cretaceous Simití, La Luna and Umir formations have type I- II oil-prone kerogen. There are also several samples from unknown origin with type III gas-prone characteristics. (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples from the Cretaceous mentioned, have reached maturity conditions for hydrocarbons generation in the basin (Figure C). There are samples that have Tmax values indicative of late to overmature maturity of the Paja, Tablazo, Simití, and La Luna formations, suggesting that the Lower Cretaceous units have reached the highest maturity in the basin.

Source Rock Characterization





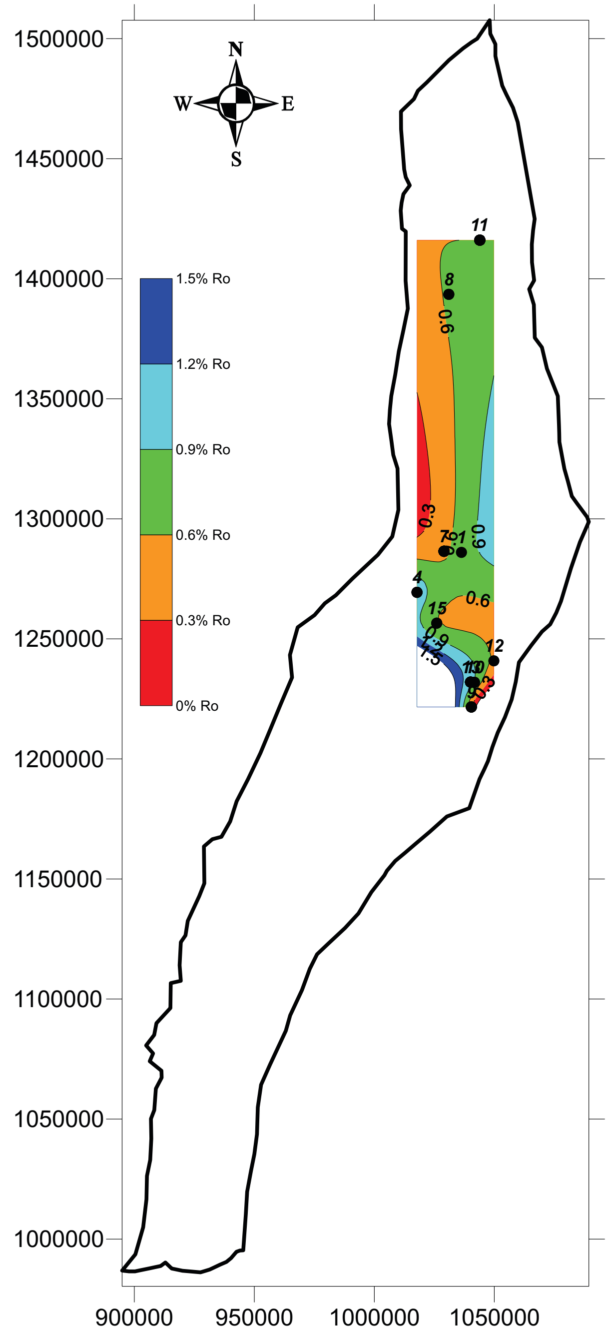
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from Cretaceous units (La Luna, Simití and Unir formations) with good to excellent oil generation potential (S2 up to 30 mg HC/g rock and % TOC up to 6). In the case of the Cenozoic units their samples indicate poor oil generation potential. There are samples with good to excellent organic matter content (%TOC ranging from 1 to 9%) but fair to poor S2 values (< 5 mg HC/ g rock) indicating that there is a small portion of labile kerogen for hydrocarbons generation (Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence ranges from immature to overmature in the basin, depending on the structural location in the basin, being more mature the wells located in the central and eastern part of the basin(Figure B).

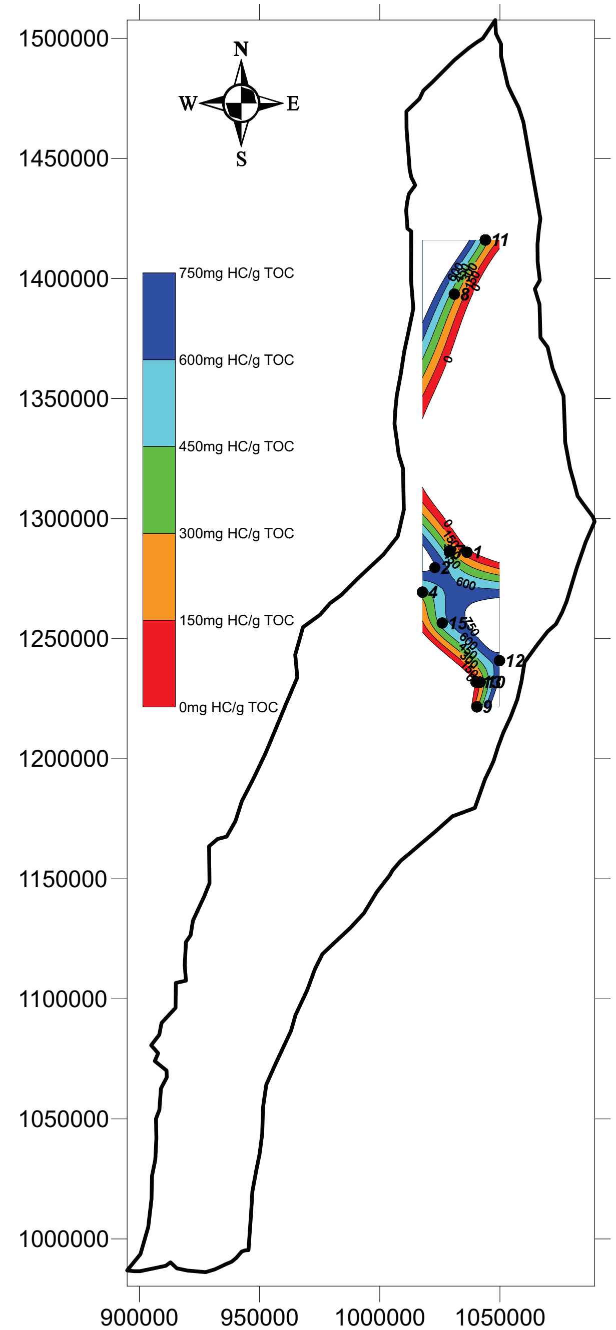
-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Cretaceous rocks of the La Luna and Umir formations.The maturity of the samples ranges from immature to gas generation window with maturity increasing in the Simití Formation and Basal Calcareous Group. The high thermal maturity reached by the Lower Cretaceous sequence could exhaust this source rocks to its present day poor generation potential.

Source Rock Quality and Maturity Maps

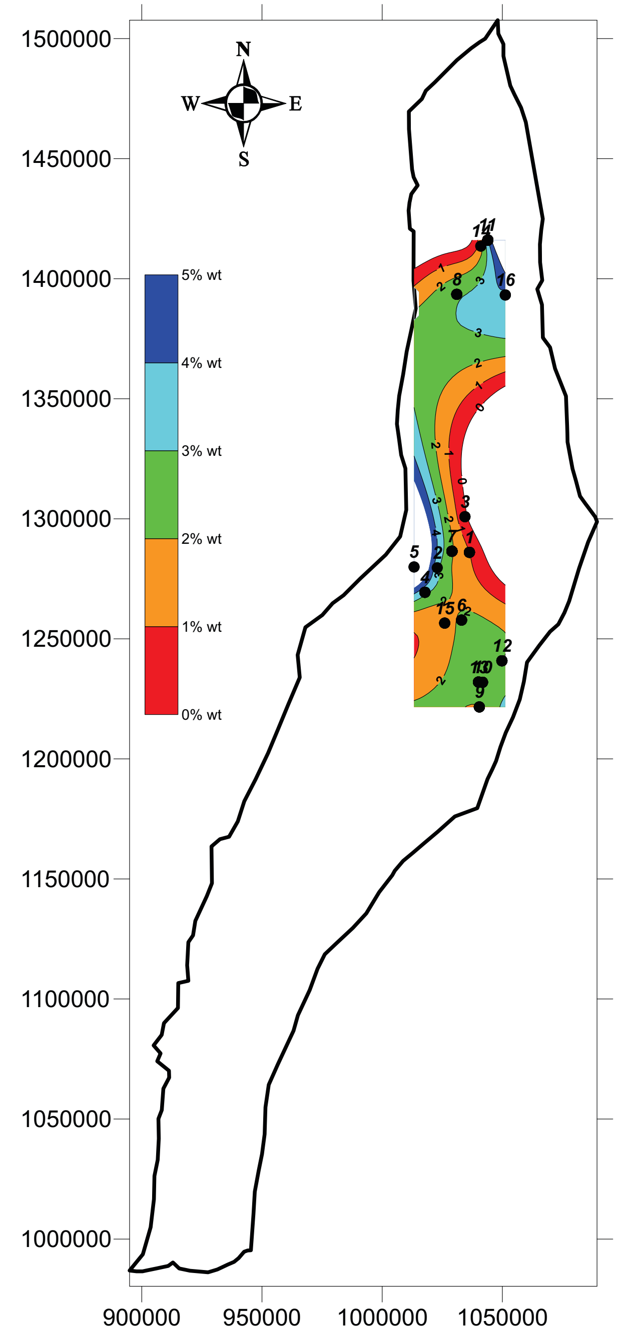
La Luna Formation



Vitrinite Reflectance (%Ro)



Hydrogen Index



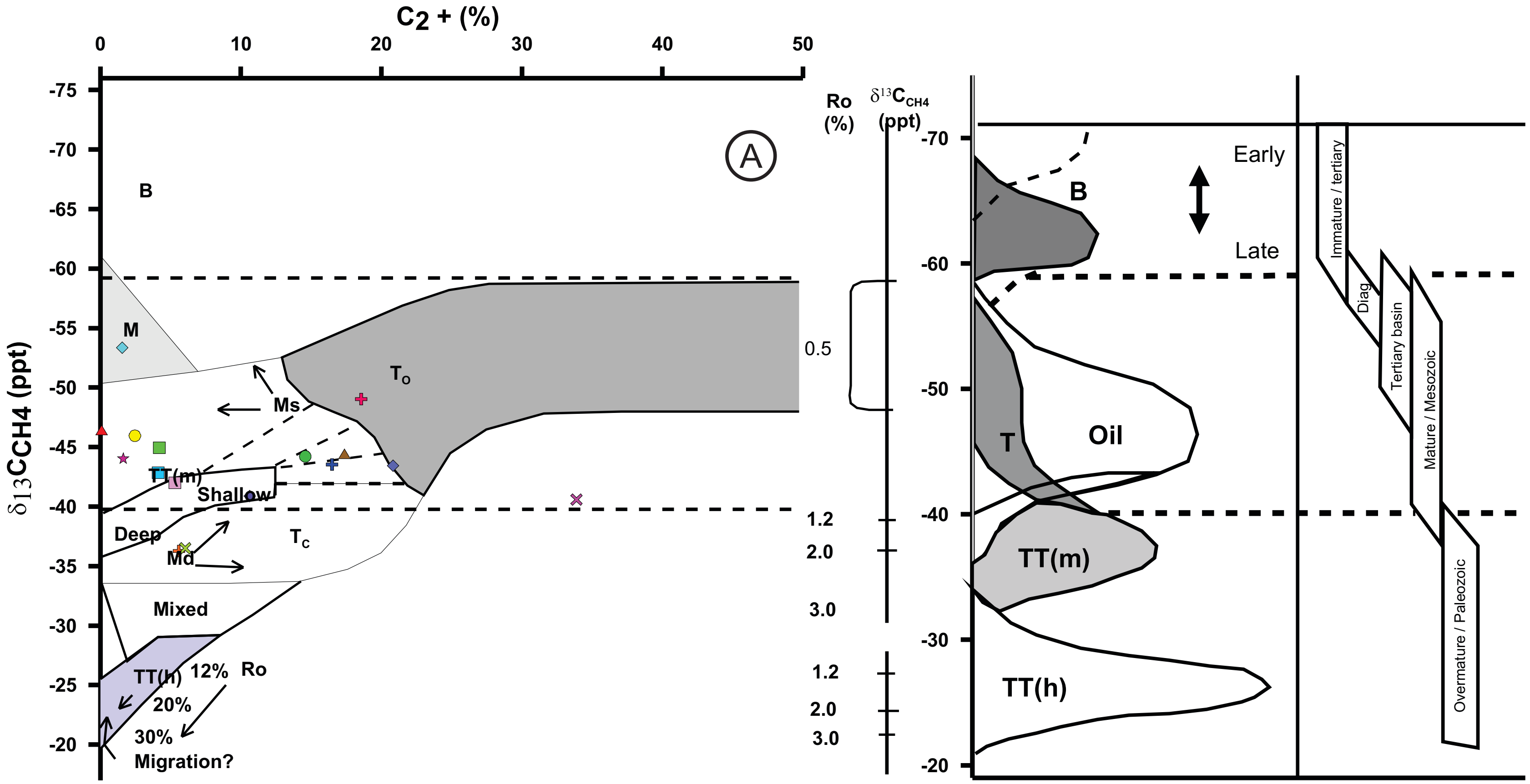
Organic Matter Content (TOC)

LEGEND

1. ARENOSA-1	5. CIMITARRA-1	9. MUGROSA SUR-1	13. PICO-1
2. BERLIN-2	6. INFANTAS-1613	10. MUGROSA-5	14. PITAL-1
3. BOSQUES-1	7. LLANITO-1	11. NOREAN-1	15. TENERIFE-1
4. CASABE-199	8. MORALES-1	12. PEÑA DE ORO-1	16. TOTUMAL-3

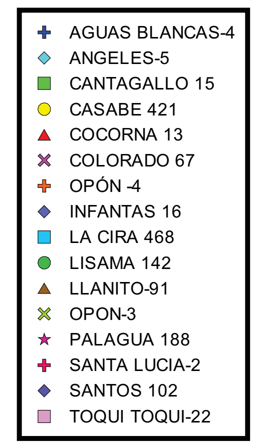
Map datum: Magna Sirgas
Coord. origin: Bogotá

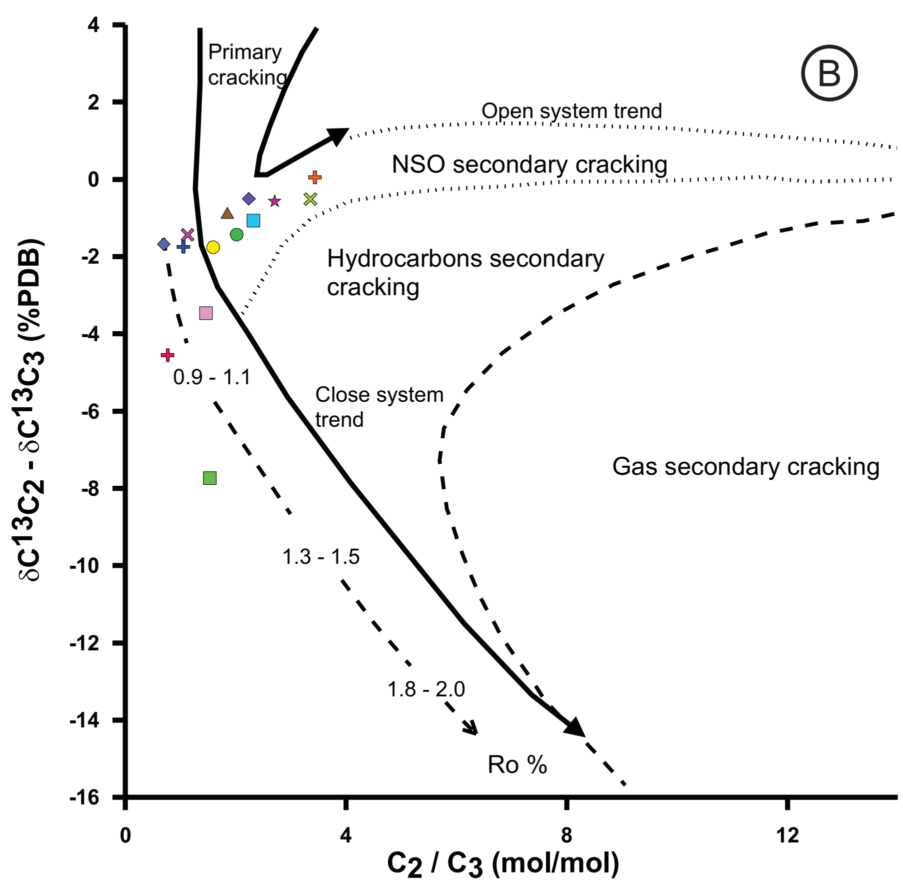
Gas Characterization



B	Biogenic gas
T	Crude oil gases
To/Tc	Crude and condensate gases
TT(m)	Dry gases associated to sapropelic organic matter.
TT(h)	Gases associated to humic organic matter
M	Mixed gases
Md	Deep Migration
Ms	Shallow Migration

LEGEND



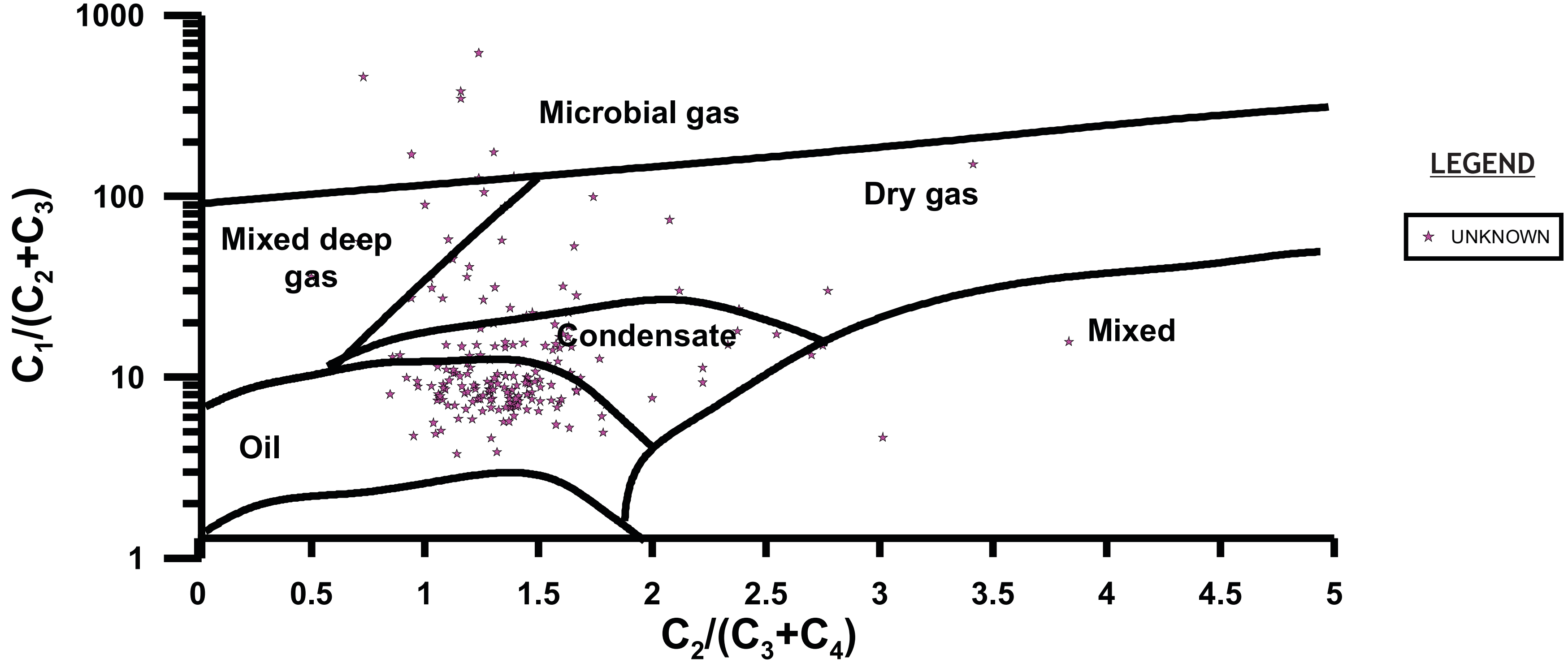


- The samples taken in the Middle Magdalena Valley basin correspond to crude oil gases.

- The C2+(%) vs d13C Ch4 (ppt) diagram (Schoell, 1983), suggests that the gas samples are thermogenic in origin and from some mixtures taking place in the reservoirs (Figure A).

- The C2/C3 vs d13C C2 - d13C C3 diagram, suggest that the gas samples analized were originated by primary cracking with increasing thermal maturity leading to NSO secondary cracking (Figure B).

Surface Geochemistry



Compositional data from surface geochemistry samples indicate that hydrocarbons are thermogenic, formed mainly during oil generation window with minor presence of high maturity hydrocarbons (gas generation window).

No mixing between different thermal maturity hydrocarbons is indicated by the data.

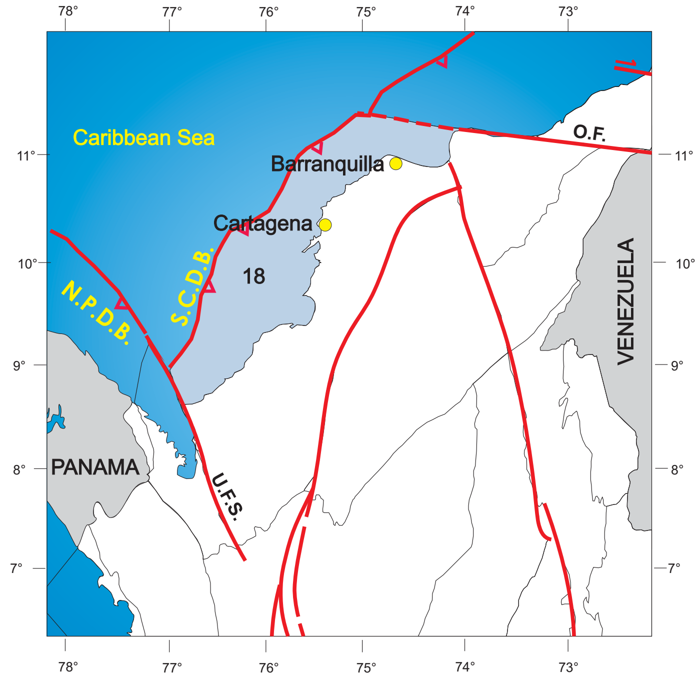
There are very few samples of microbial gas to consider biogenic gas an important process in the basin.

SINÚ OFFSHORE BASIN

Generalities
Wells and Seeps
Source Rock Characterization

Generalities

SINÚ OFFSHORE BASIN
LOCATION AND BOUNDARIES



N.P.D.B. North Panama Deformed Belt

From Barrero et al., 2007

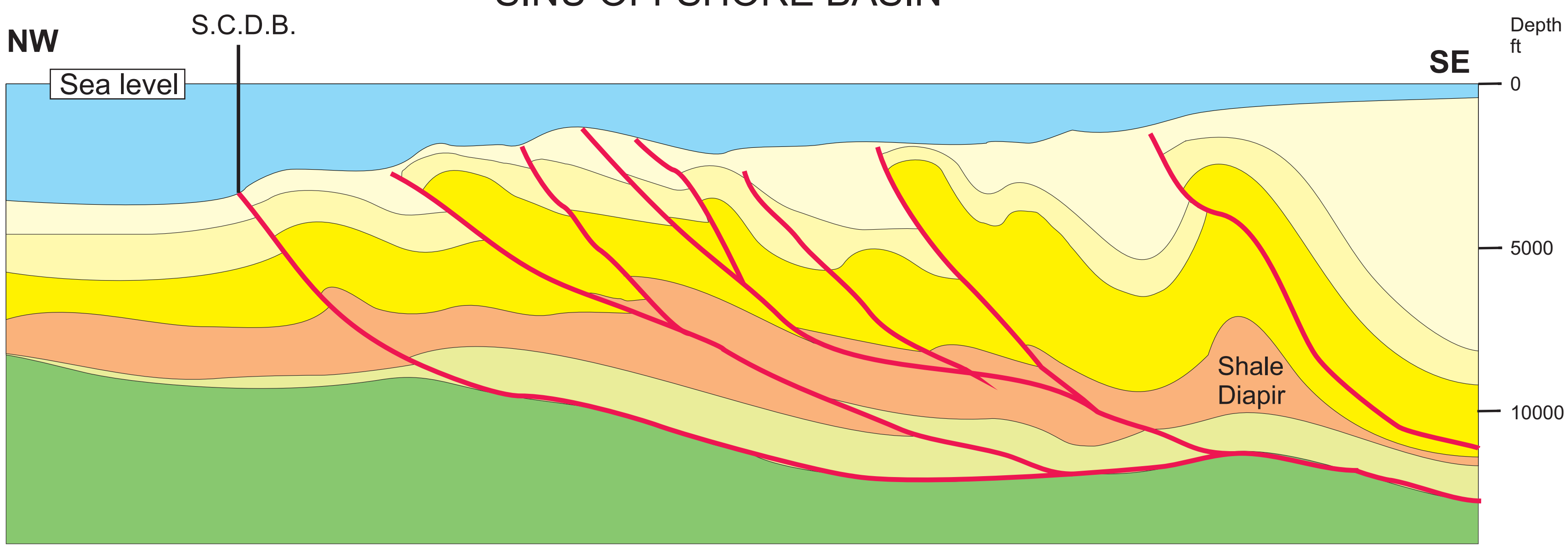
BOUNDARIES

Northeast: Oca fault (O.F.)
Northwest: South Caribbean Deformed Belt deformation front (S.C.D.B)
Southeast: Present day shoreline
Southwest: Uramita fault system (U.F.S)

The source rock geochemical information interpreted for the Sinú Offshore Basin includes %TOC and Rock-Eval Pyrolysis data from 218 samples taken in 5 wells; additionally 54 organic petrography samples from 10 wells were interpreted.

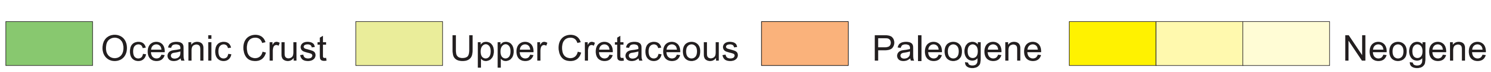
Due to the lack of crude oil geochemical data, crude oil interpretation was not made for the basin.

SCHEMATIC CROSS SECTION
SINU OFFSHORE BASIN



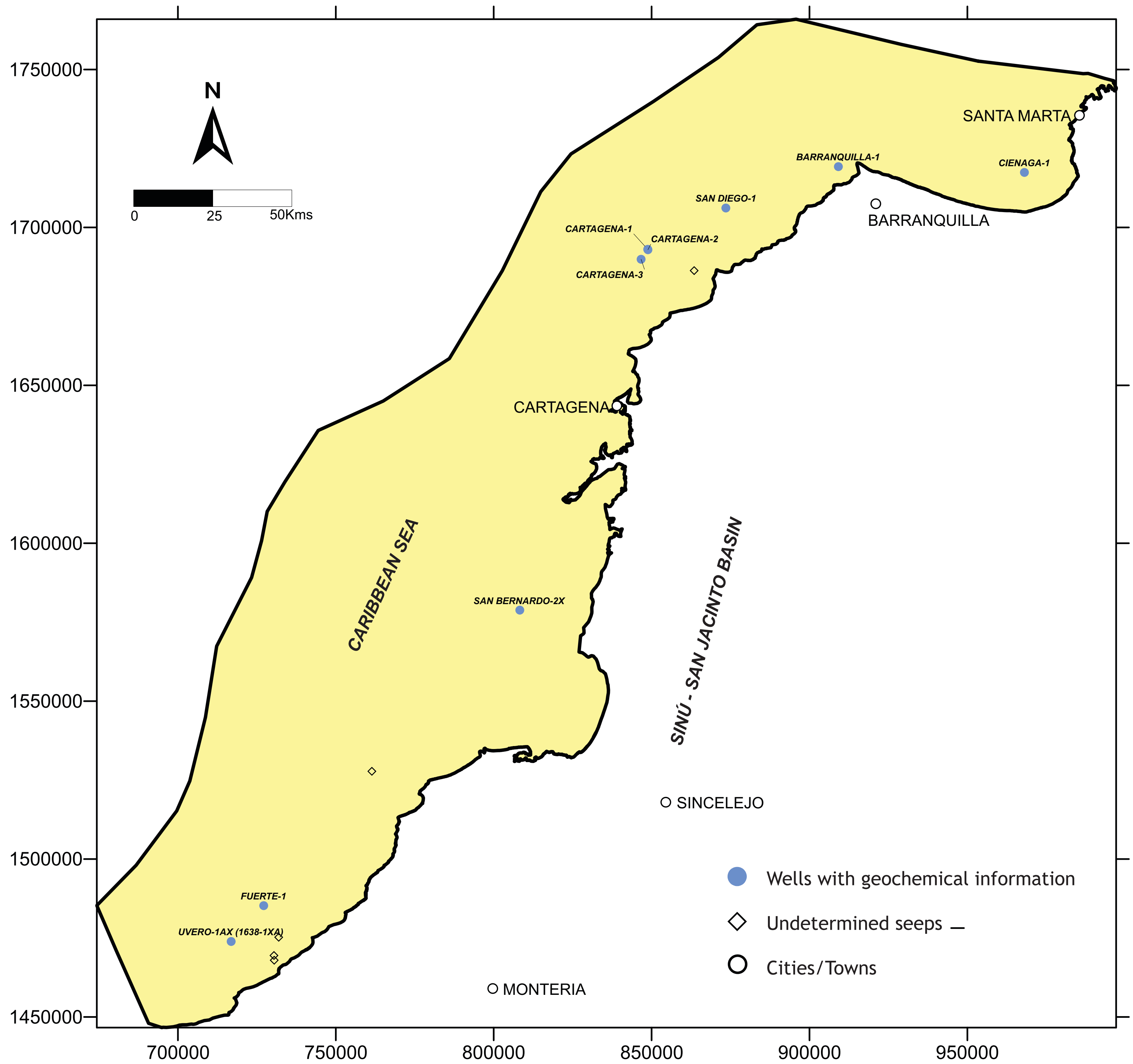
Modified from Amaral, et al., 2003.

Color code according to the commission for the Geological Map of the World (2005)



From Barrero et al., 2007

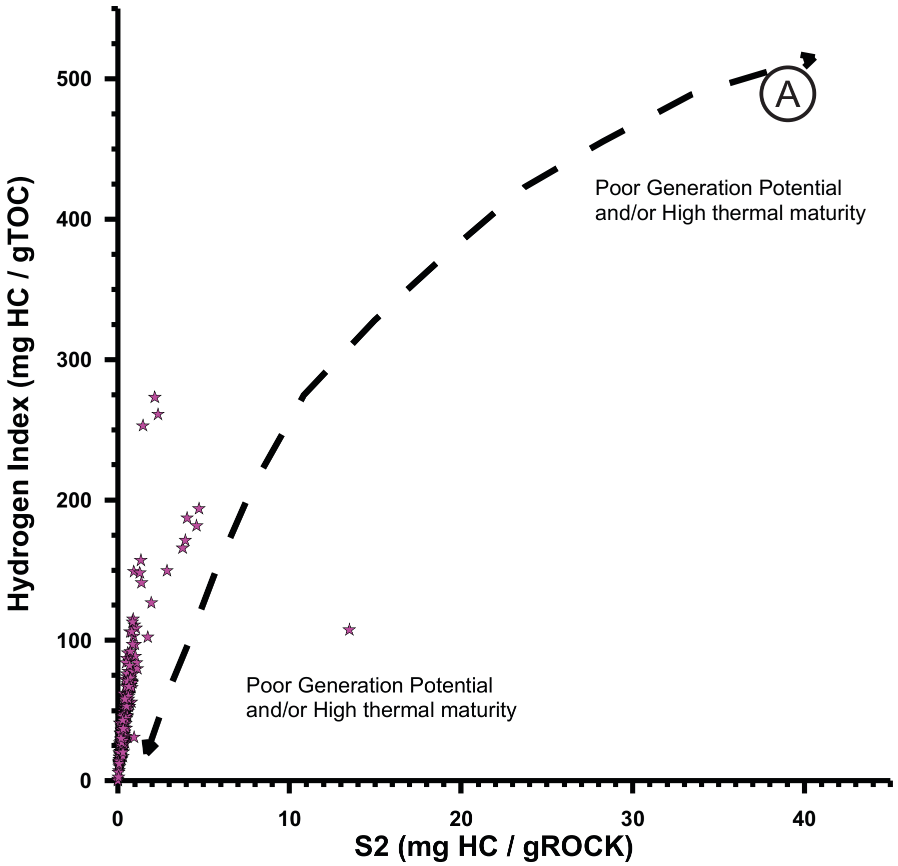
Wells and Seeps

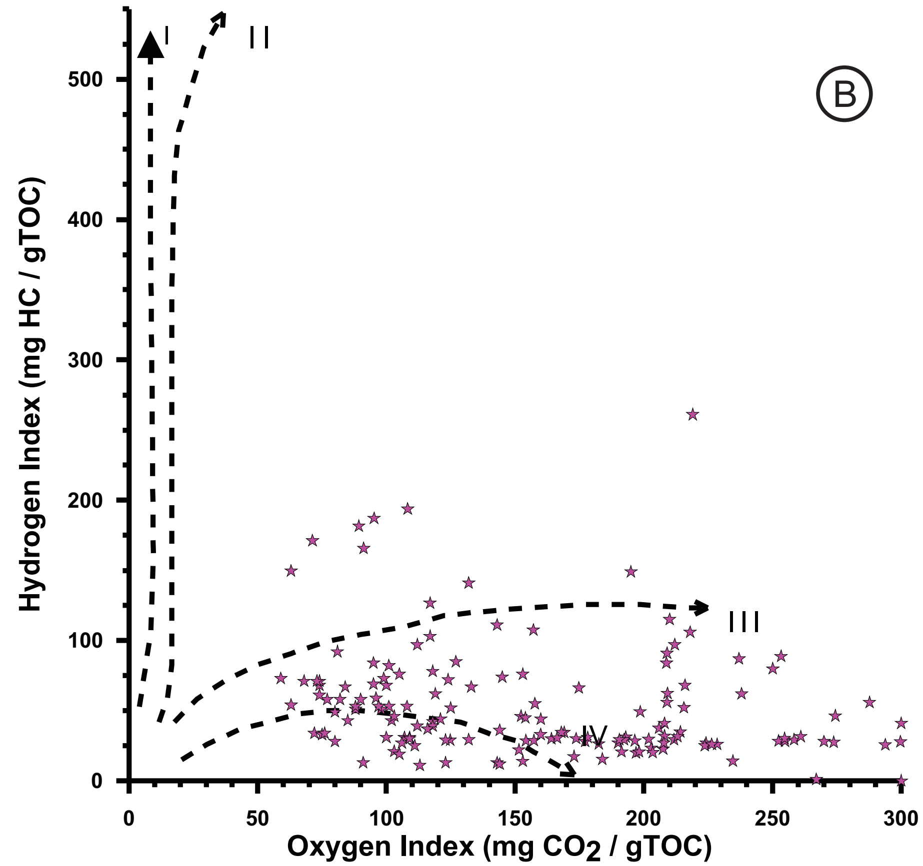


Map datum: Magna Sirgas
Coord. origin: Bogotá

The number of wells and/or surface locations with geochemical information in the Sinú Offshore Basin is 9.

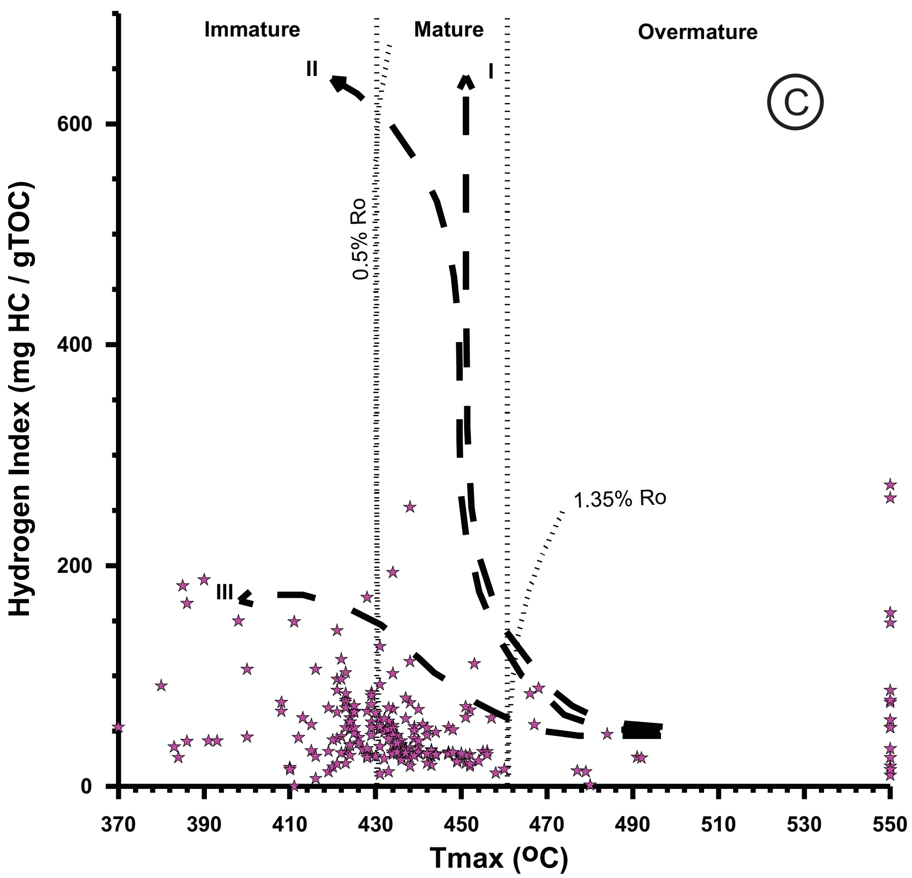
Source Rock Characterization





LEGEND

★ UNKNOWN

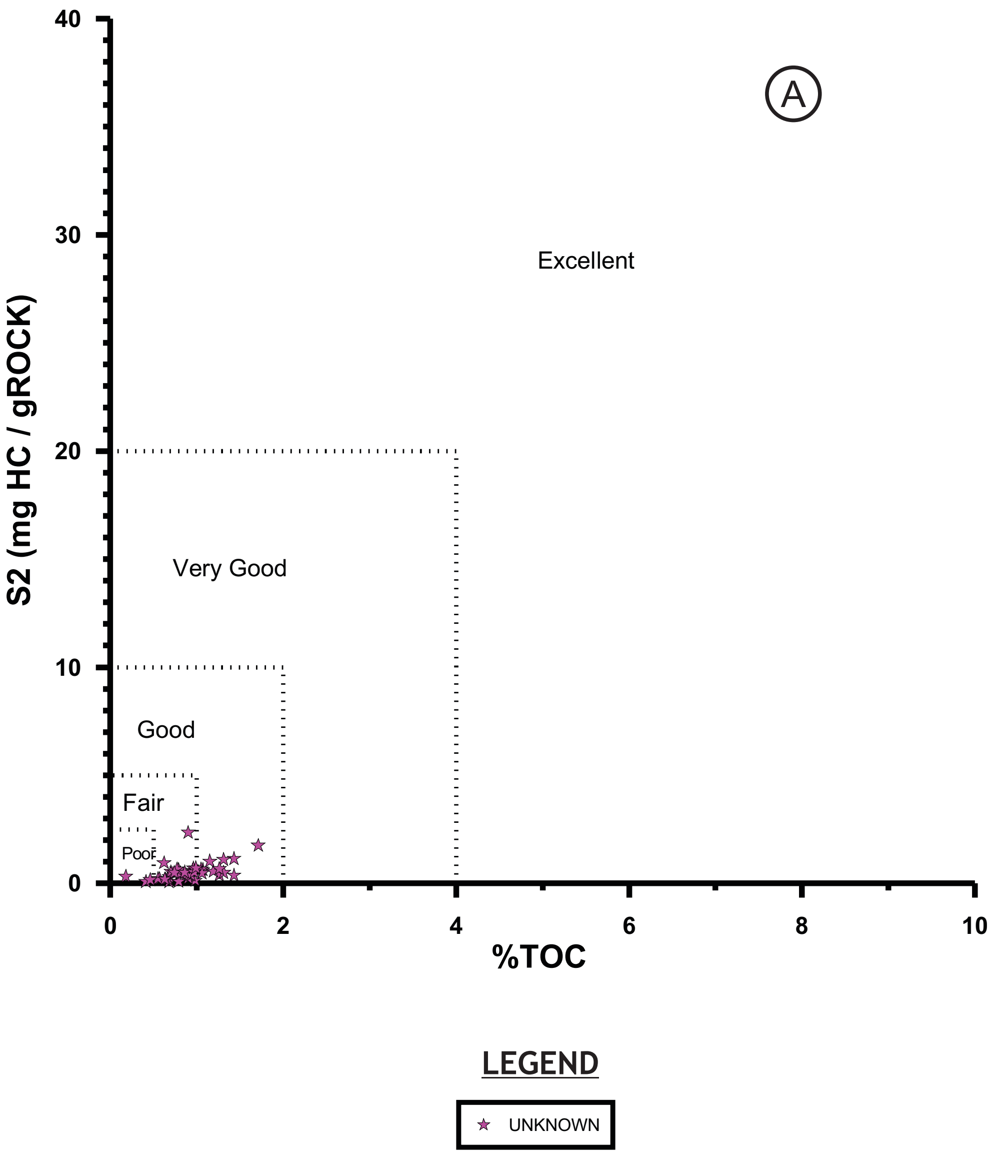


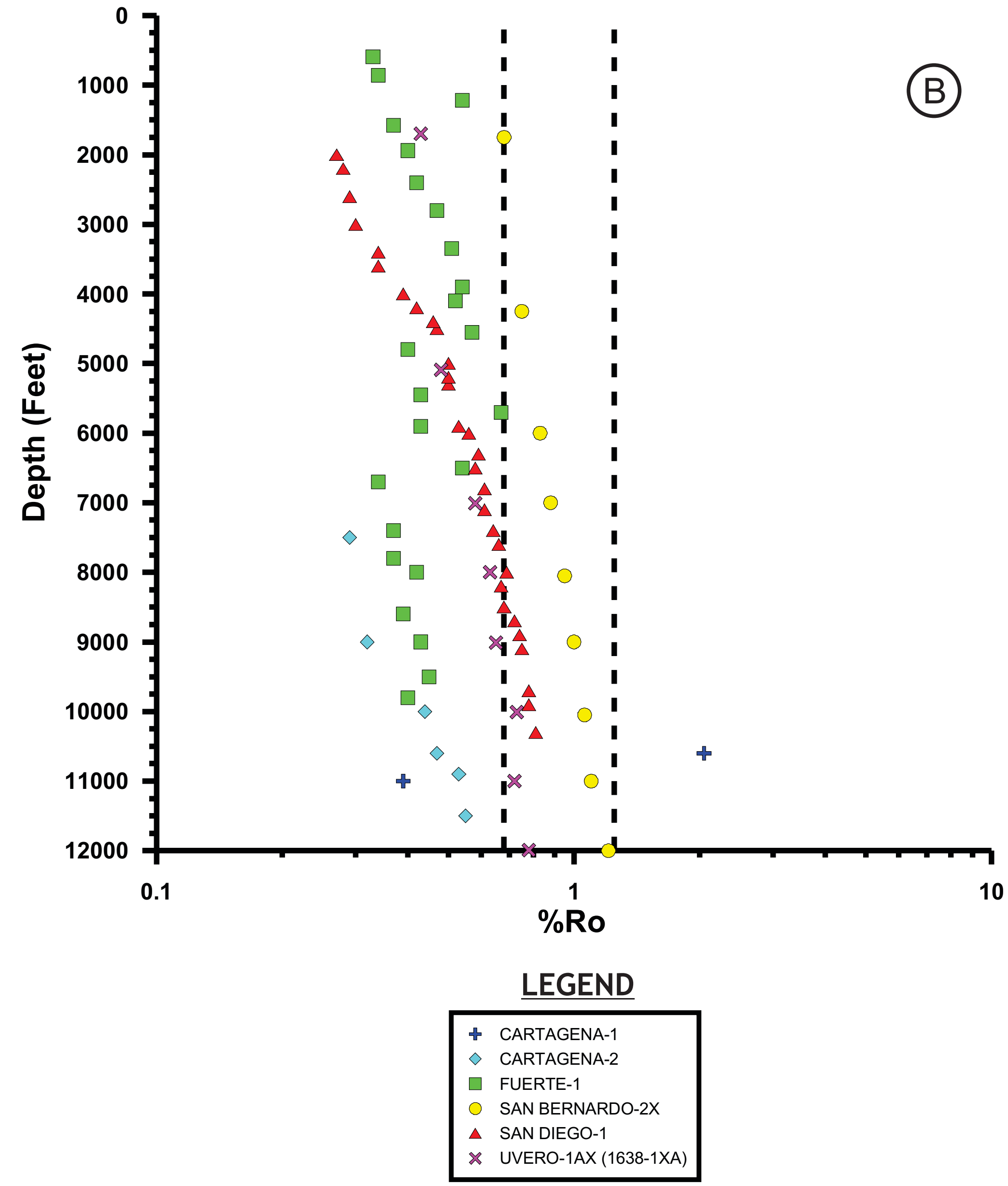
- The data obtained from pyrolysis Rock-Eval of rock samples for Hydrogen Index (HI) and S2 peak, indicate that the source rocks in the basin have poor generation potential (HI < 200mg HC / g TOC and S2 < 5 mg HC / g rock) (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples in the basin have type III gas-prone kerogen to type IV kerogen. (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples fhave reached early maturity to overmature conditions in the basin (Figure C). The high thermal maturity of these samples could cause kerogen depletion indicated by the low Hydrogen Index and S2 values of some samples in figure A.

Source Rock Characterization





- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that the samples from potential source rocks in the basin, have poor oil generation potential (S2 < 2.5 mg HC/g rock and %TOC < 2) (Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence is immature or close to early maturity in most wells in the basin, with some samples up to late generation window (Figure B).

The high thermal maturity reached by the sedimentary sequence in some wells, according to Tmax and %Ro data, suggests that there are thermal conditions for hydrocarbons generation. Being the main concern in the basin the quality of the source rocks, because so far no good quality source for liquid hydrocarbons has been found, and the pyrolysis samples suggests the existence of gas-prone source rocks.

SINÚ - SAN JACINTO BASIN

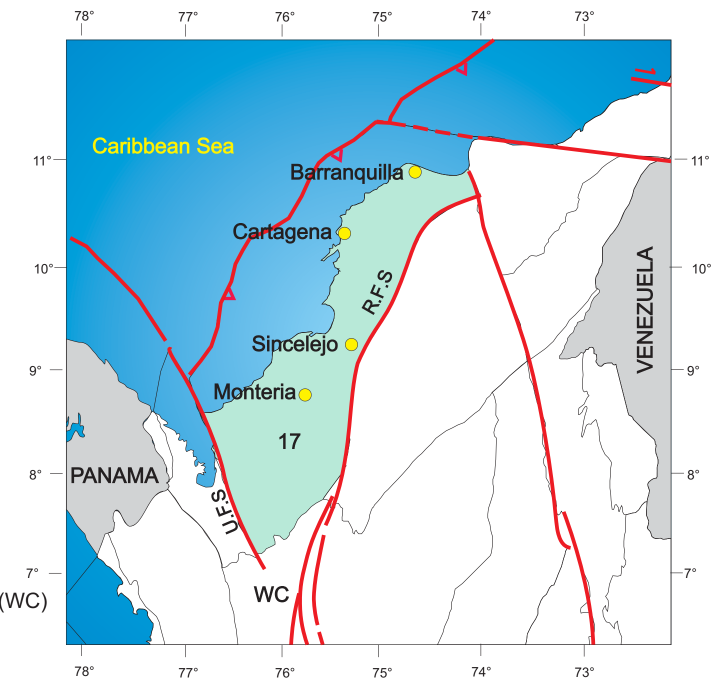
Generalities
Wells and Seeps
Crude Oil Quality
Source Rock Characterization
Surface Geochemistry
Petroleum Systems (Crude-Rock Correlations)

Generalities

The source rock geochemical information interpreted for the Sinú - San Jacinto Basin includes %TOC and Rock-Eval Pyrolysis data from 836 samples taken in 32 wells; additionally 56 organic petrography samples from 11 wells were interpreted.

Crude oil and extracts information from 13 bulk analysis samples, 160 liquid chromatography samples, 1534 gas chromatography samples, 129 biomarker samples, 71 isotopes samples and 854 surface geochemistry samples were also interpreted.

SINÚ - SAN JACINTO BASIN
LOCATION AND BOUNDARIES

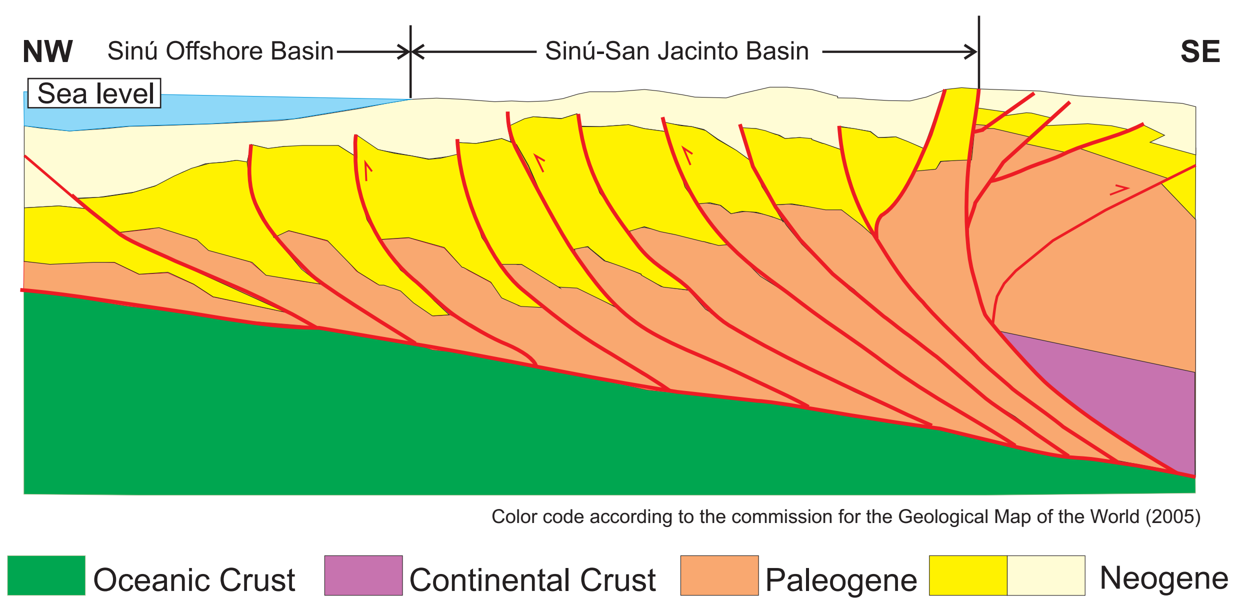


BOUNDARIES

North- northwest: Present Caribbean coast
East: Romeral fault system (R.F.S.)
South: Cretaceous rocks of the Western Cordillera (WC)
West: Uramita fault system (U.F.S.)

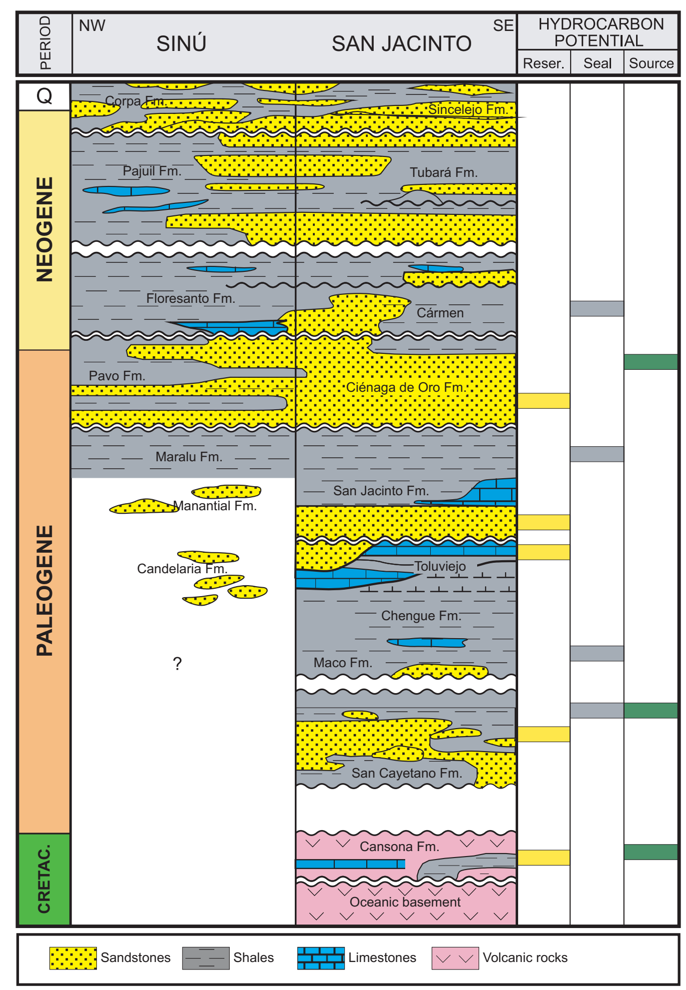
From Barrero et al., 2007

SCHEMATIC CROSS SECTION
SINÚ - SAN JACINTO BASIN



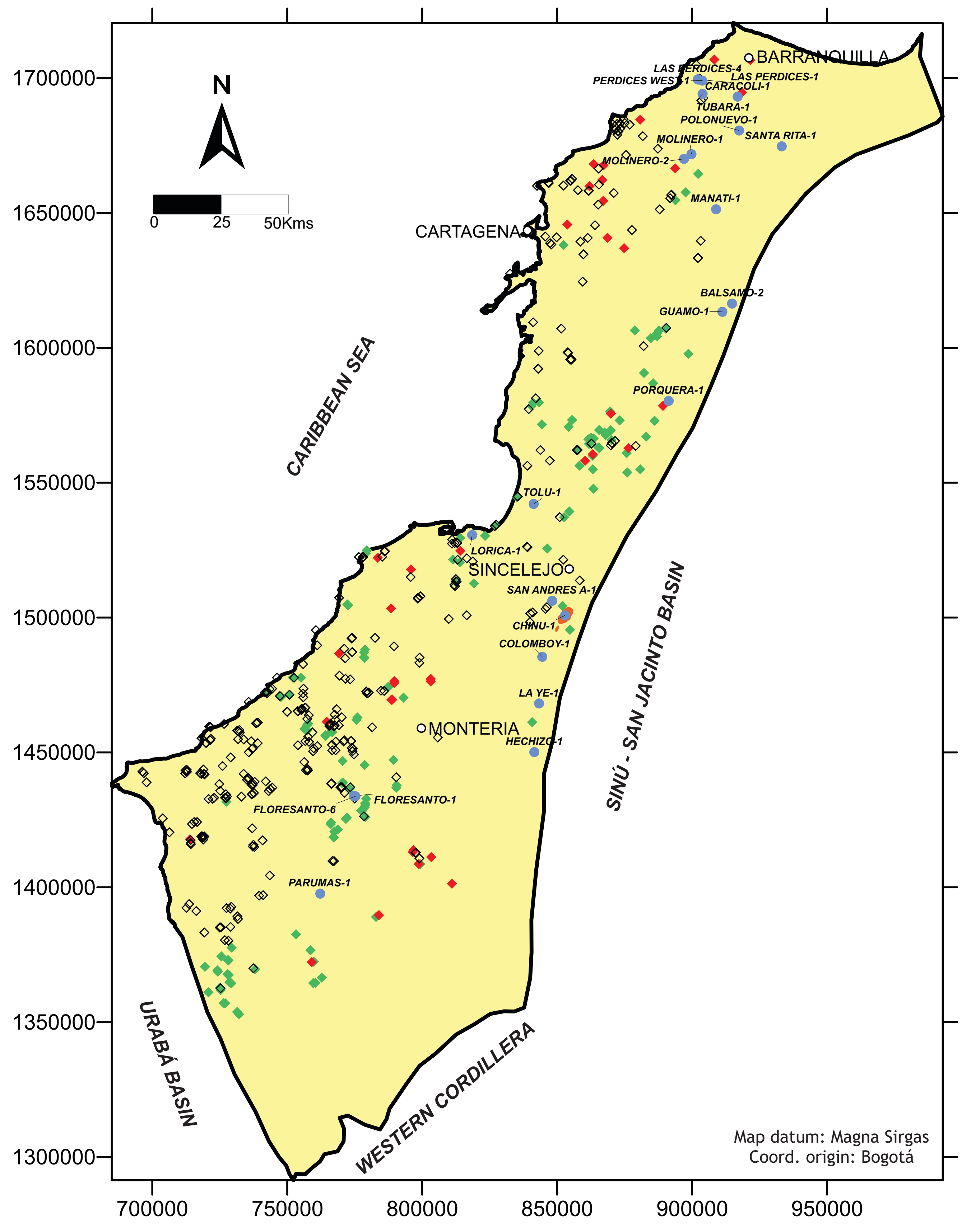
Color code according to the commission for the Geological Map of the World (2005)

From Barrero et al., 2007



From Barrero et al., 2007

Wells and Seeps

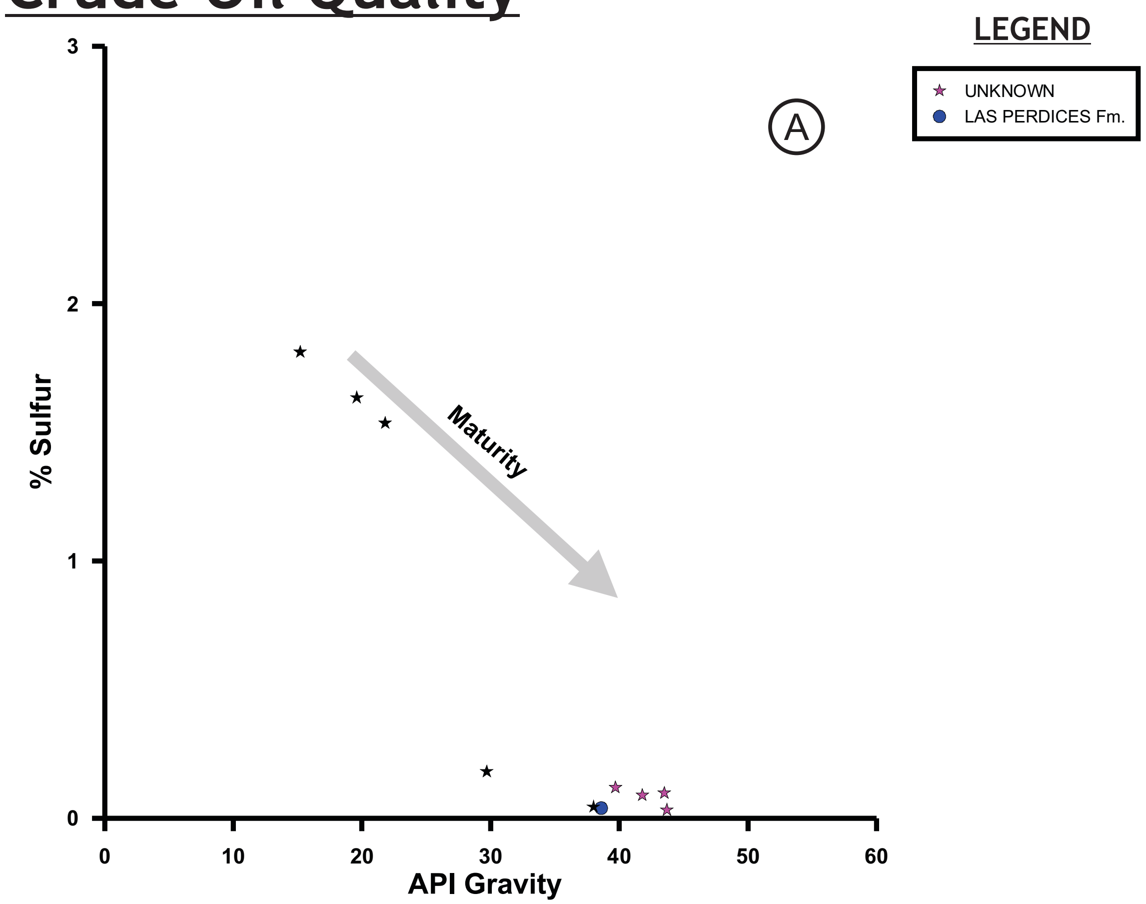


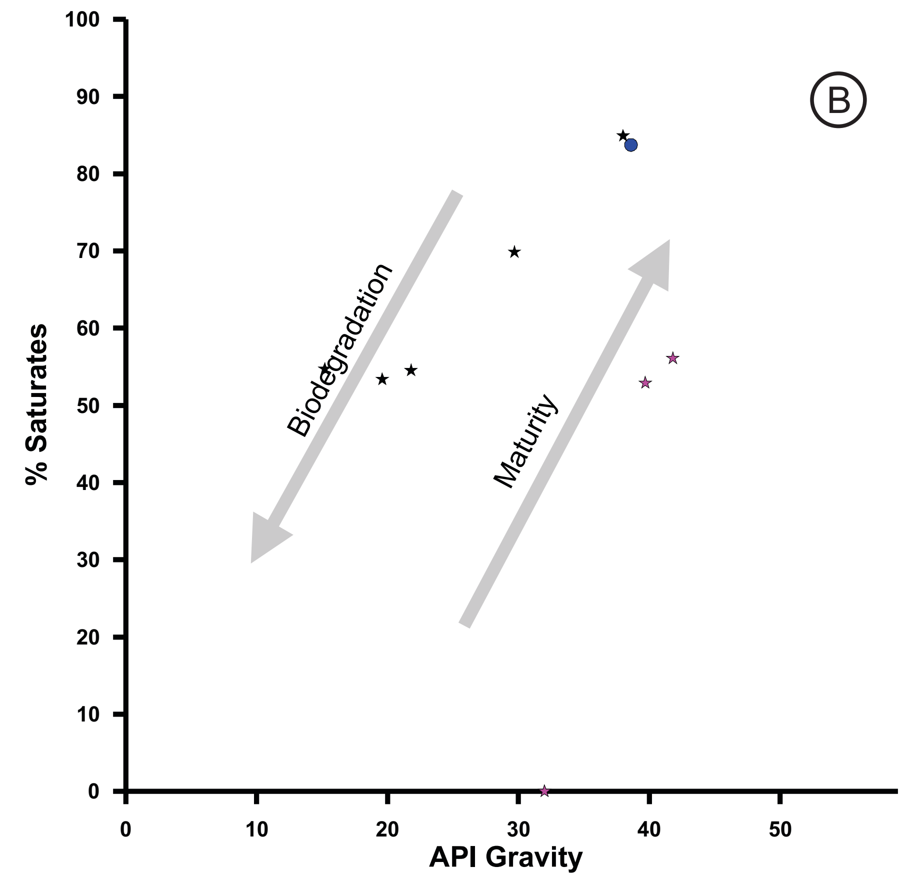
The number of wells and/or surface locations with geochemical information in the Sinú - San Jacinto Basin is 23.

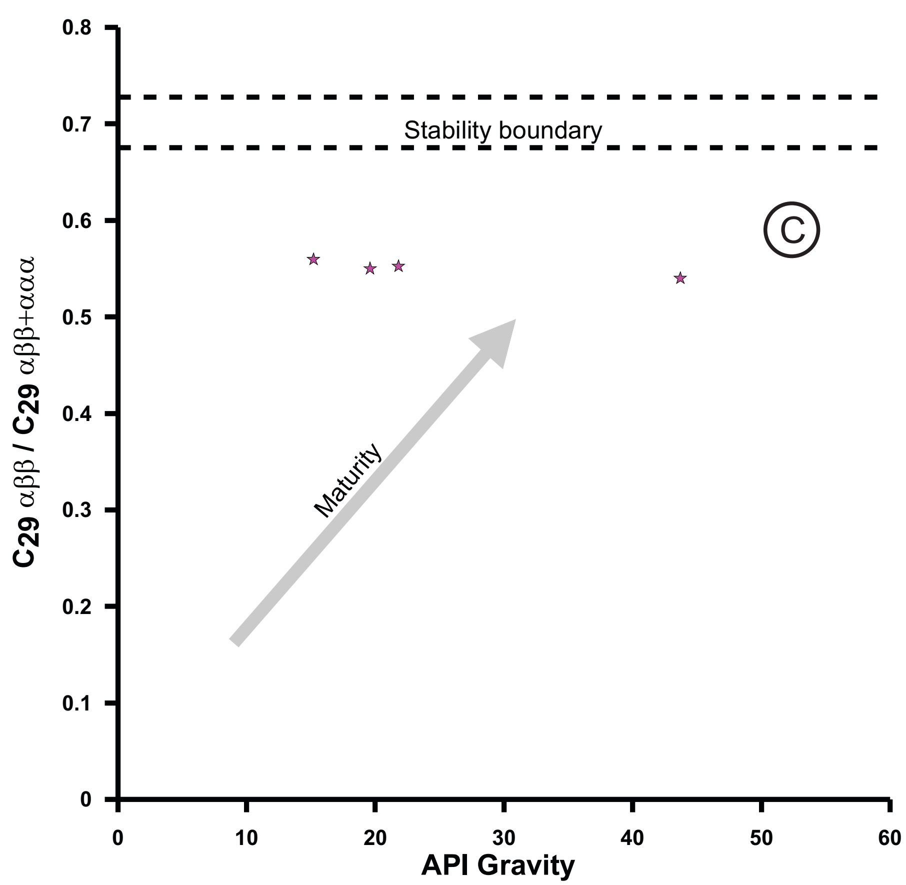
Oil and gas seeps are located widespread in the basin.

- Oil and gas fields
- Wells with geochemical information
- Oil seeps
- Gas seeps
- Undetermined seeps
- Cities/Towns

Crude Oil Quality





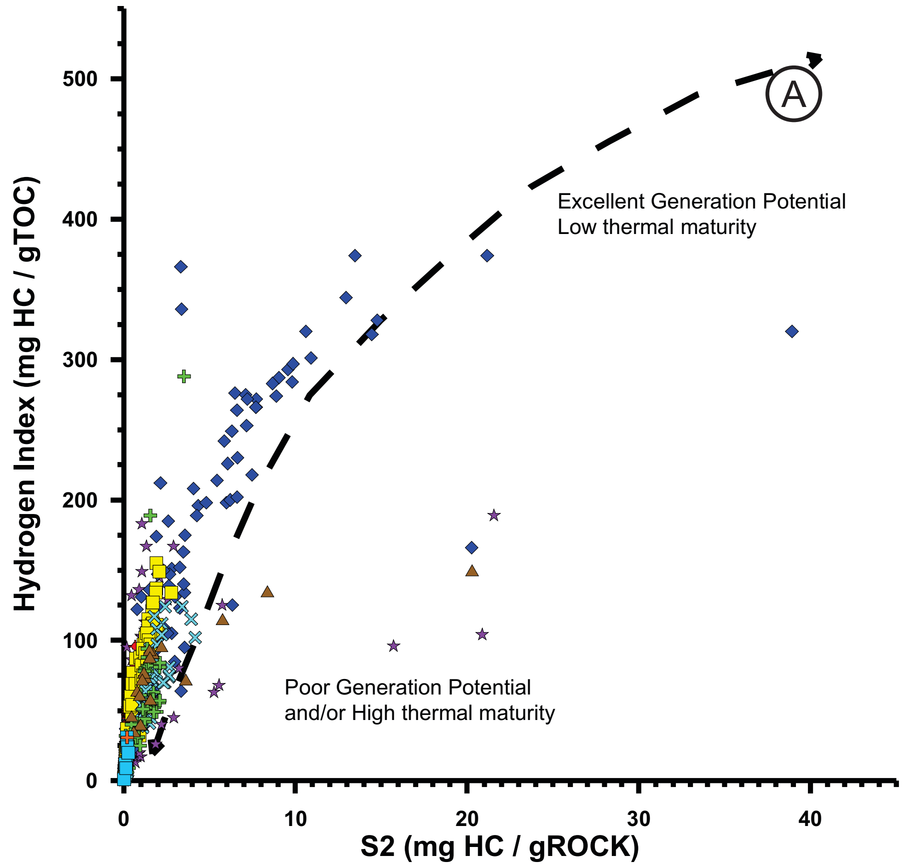


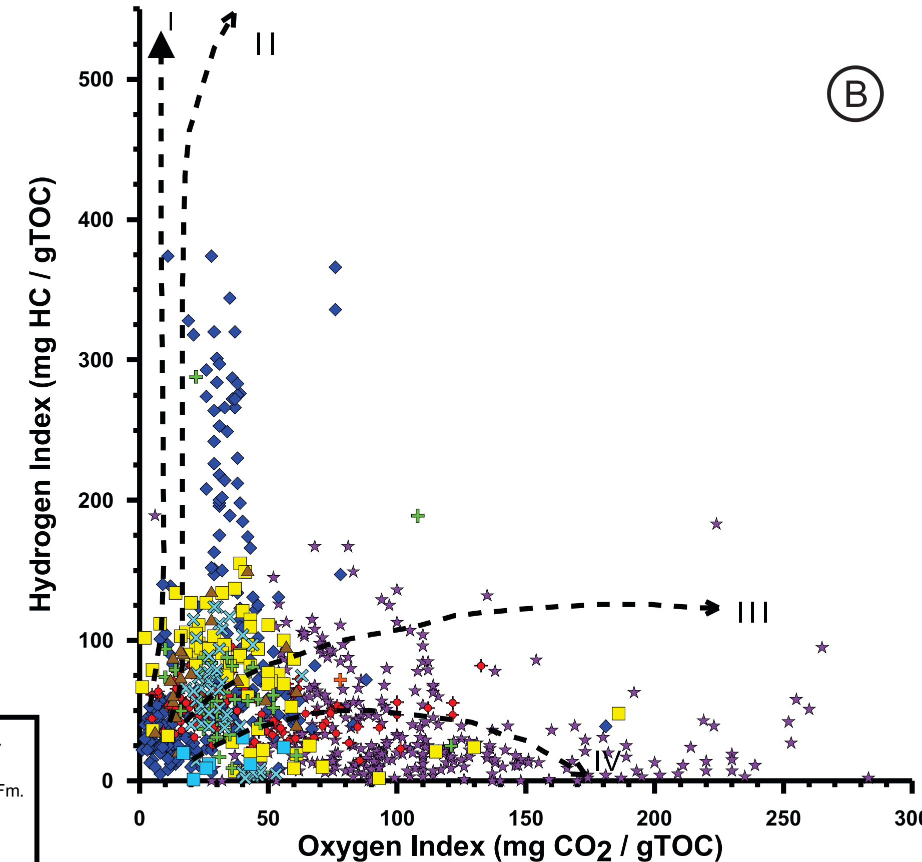
- Normal and light oils with API gravities ranging from 10° to 45° and sulfur content below 2% are present in the basin. There is good correlation between sulfur and API gravity, with low API gravity oils having higher sulfur content than high API gravity oils. This suggests that in the basin there are oils with different thermal maturities and/or preservation (biodegradation) (Figure A).

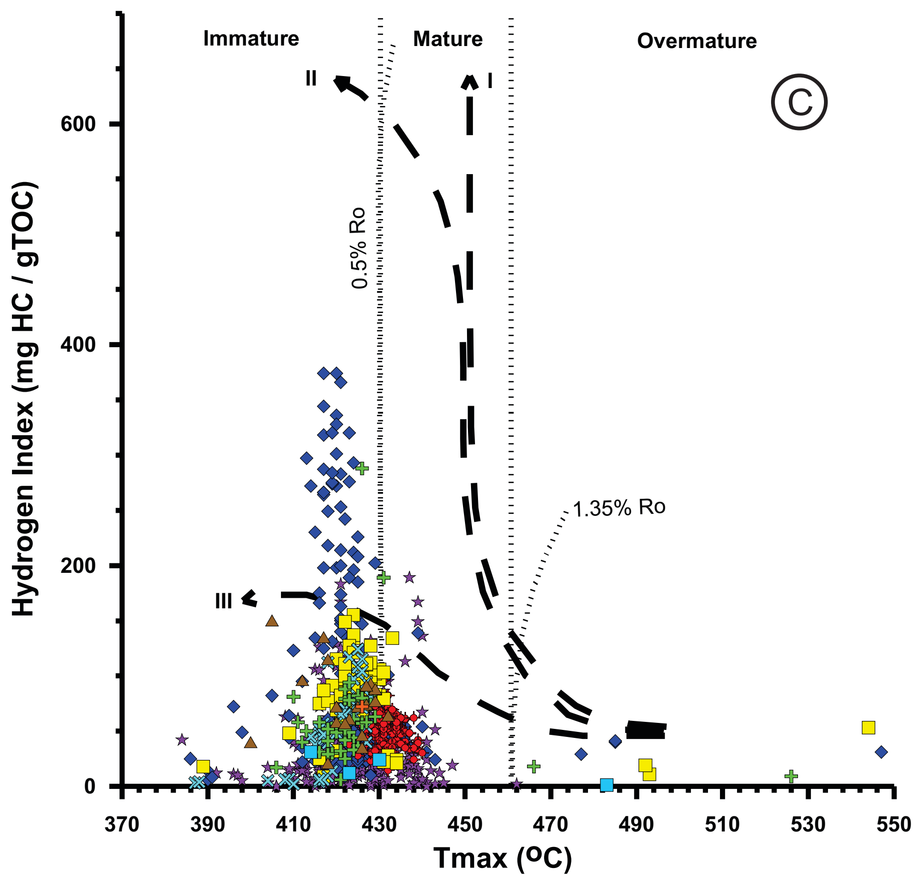
- Additional supporting evidence of different thermal maturities and preservation of the crude oils can be seen in the API gravity vs %Saturates graph. In this two trends, one of low API gravity (<25°) in which saturates percentage diminishes as a result of biodegradation, and the other of high API gravity (>25°) in which saturates percentage increases with maturity (Figure B).

- The API Gravity vs C29aBB/C29aBB+aaa graph, shows that oils with high and low API gravity has similar C29 isomerization levels suggesting similar thermal maturity, and also that the low API gravity could be the result of biodegradation of a higher maturity crude oil. (Figure C).

Source Rock Characterization







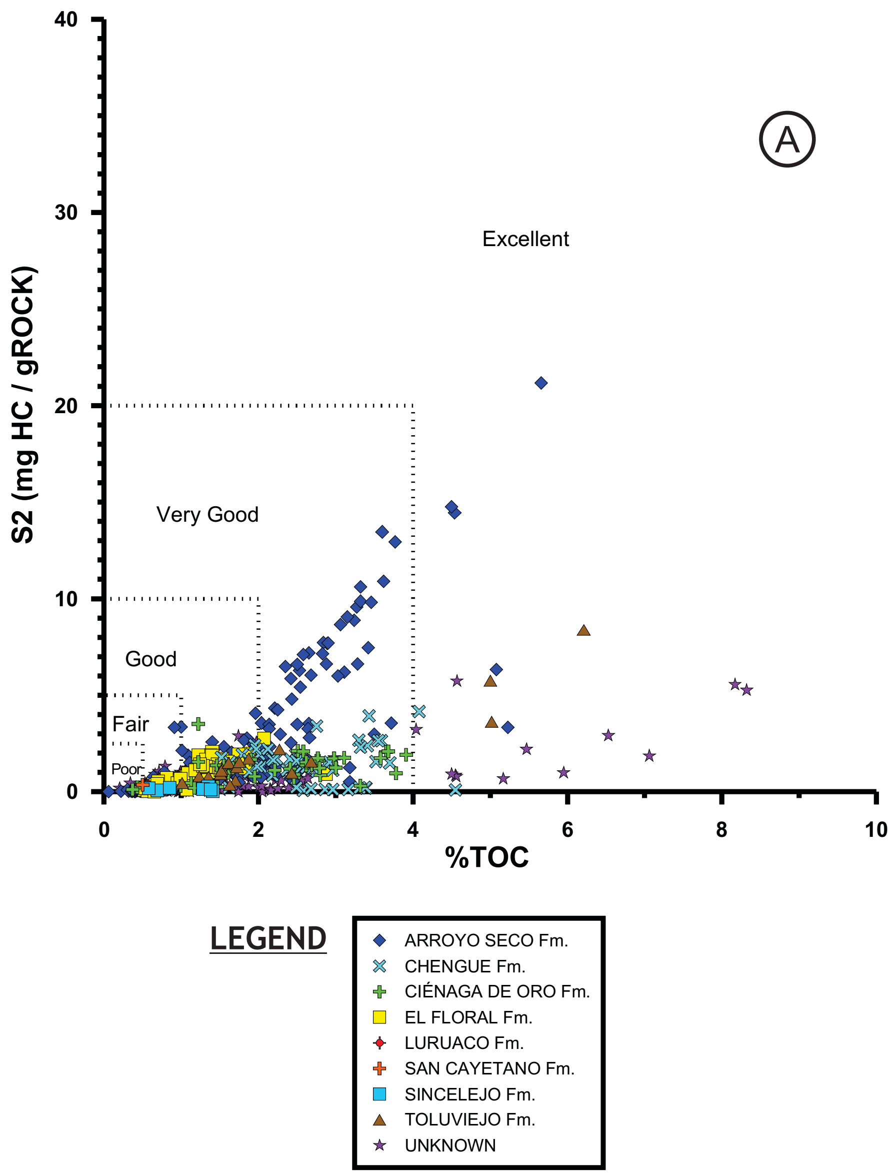
- The data obtained from pyrolysis Rock-Eval of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Paleocene Arroyo Seco Formation have good generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock). The rest of Cenozoic all have poor generation potential in the basin (Figure A).

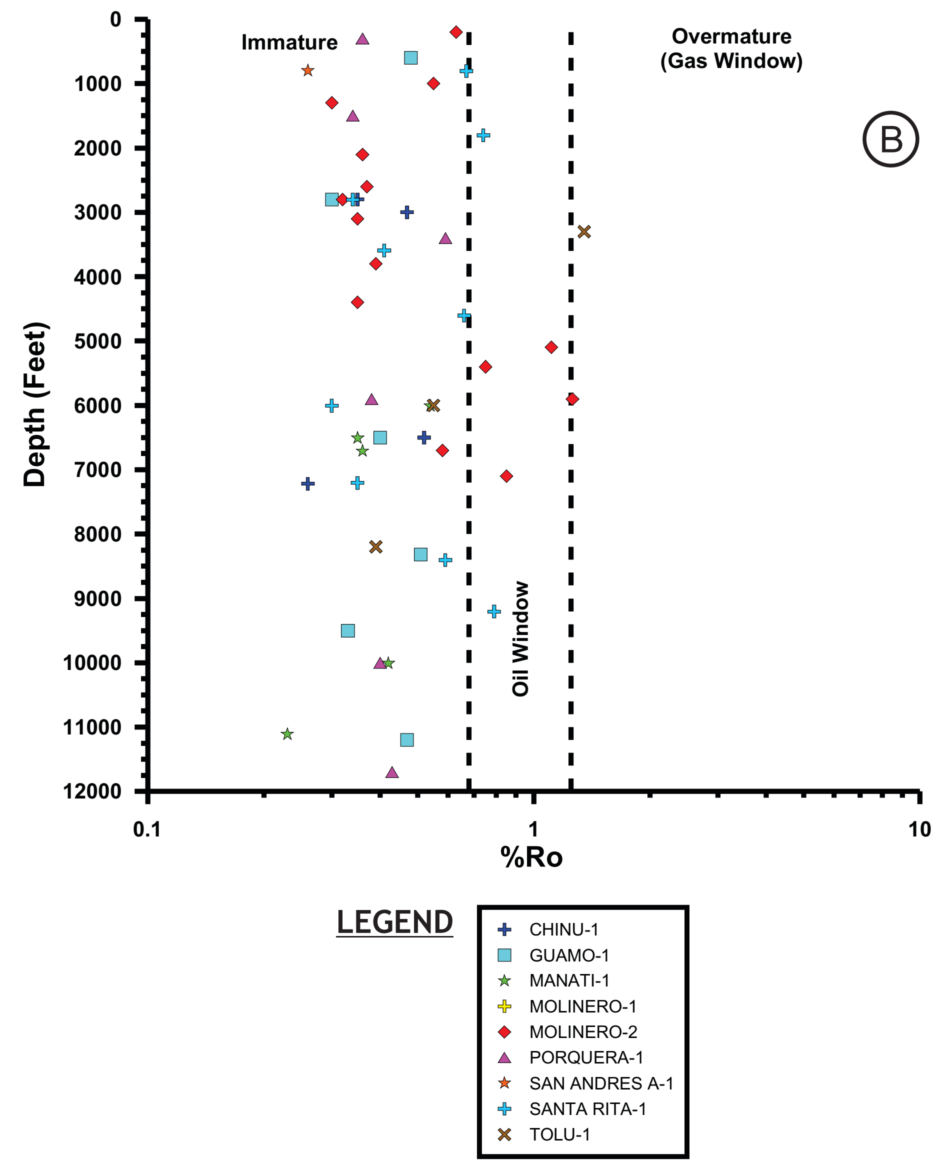
- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Paleocene Arroyo Seco Formation have type II oil-prone kerogen. For the rest of the Cenozoic units (San Cayetano, Toluviejo, Chengue, El Floral, Luruaco, Ciénaga de Oro and Sincelejo formations) their samples are indicative of type III gas-prone kerogen to type IV kerogen (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that the samples from the Cenozoic units mentioned, have reached early maturity to oil generation peak conditions in the basin (Figure C).

- The presence of a source rock with type II kerogen (Arroyo Seco Formation) in the basin as shown by the pyrolysis data, suggests that the many oil seeps reported in the basin could have origin , at least in part from this formation.

Source Rock Characterization



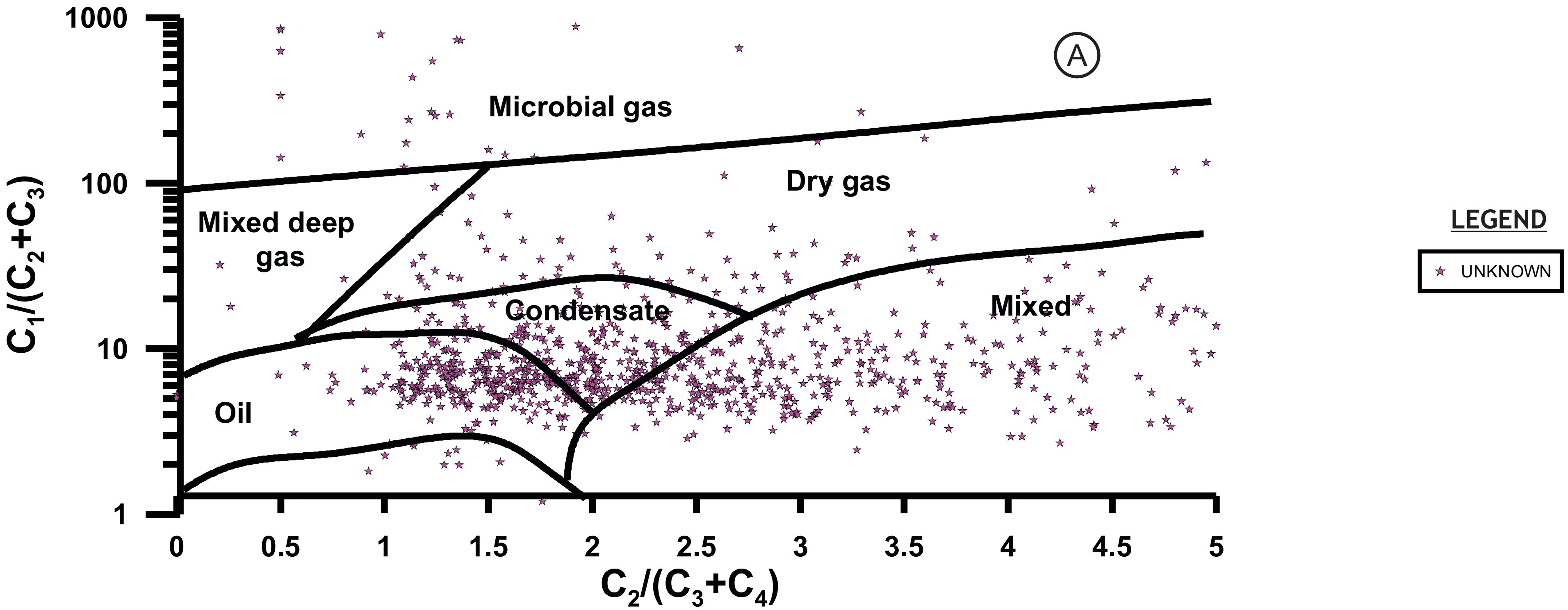


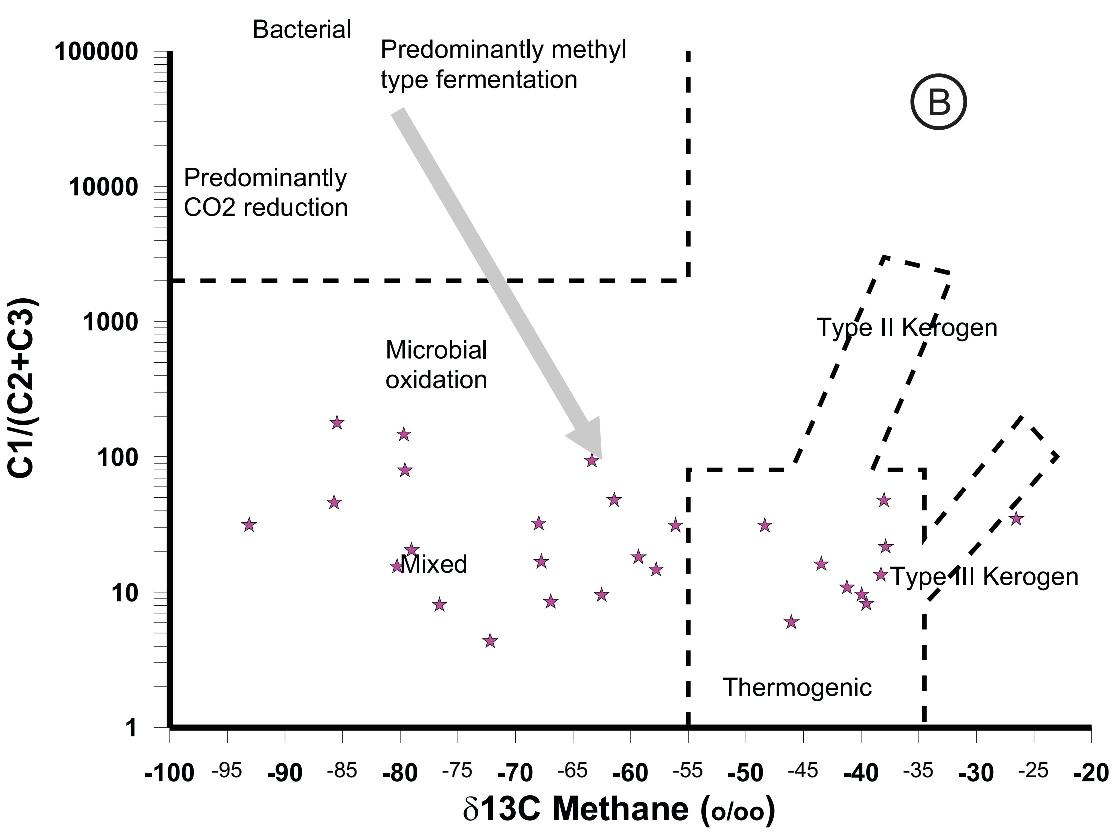
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from the Paleocene Arroyo Seco Formation with good to excellent oil generation potential (S2 up to 50 mg HC/g rock and % TOC up to 9). There are samples with good to very good %TOC but poor S2 values of the Chengue, Toluviejo and Ciénaga de Oro formations, which suggest that the labile portion of the kerogen is poor to generate liquid hydrocarbons (Figure A).

-The vitrinite reflectance (%Ro) information shows that in most wells the sedimentary sequence is immature or close to early maturity in the basin, with fewer wells reaching higher levels of thermal maturity. (Figure B).

-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Paleocene rocks of the Arroyo Seco Formation. The rest of the Cenozoic rocks have poor oil generation potential. Maturity data indicate that the sedimentary sequence has reached thermal maturity, explaining the very important presence of oil seeps in the basin.

Surface Geochemistry



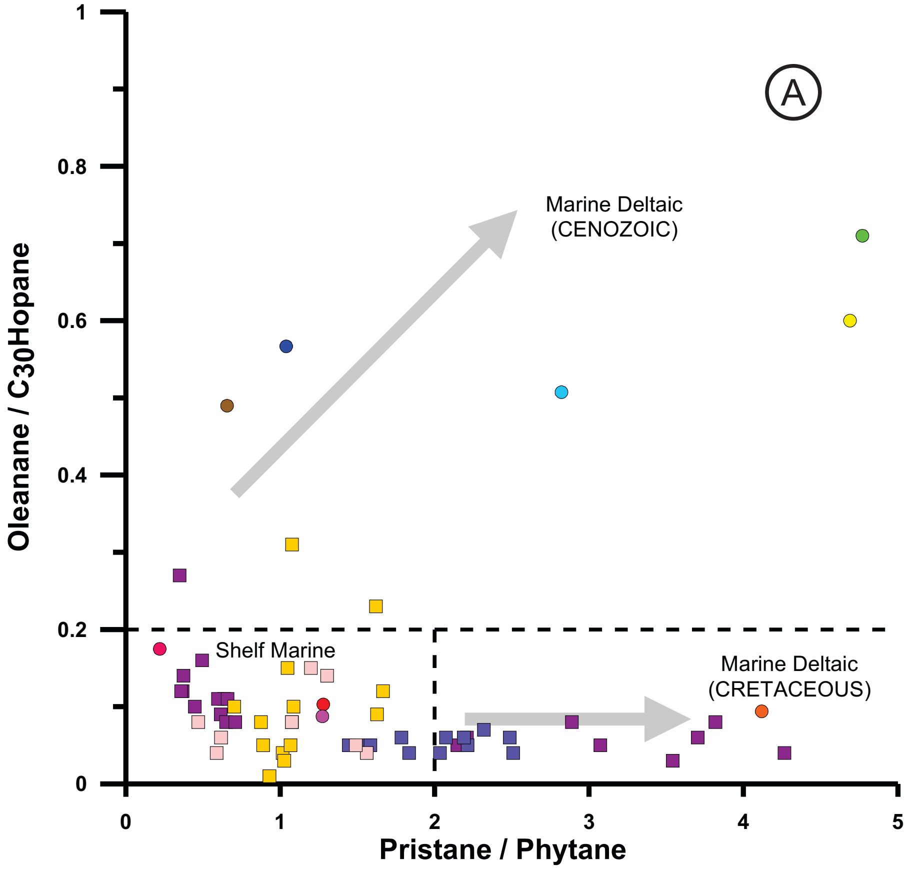


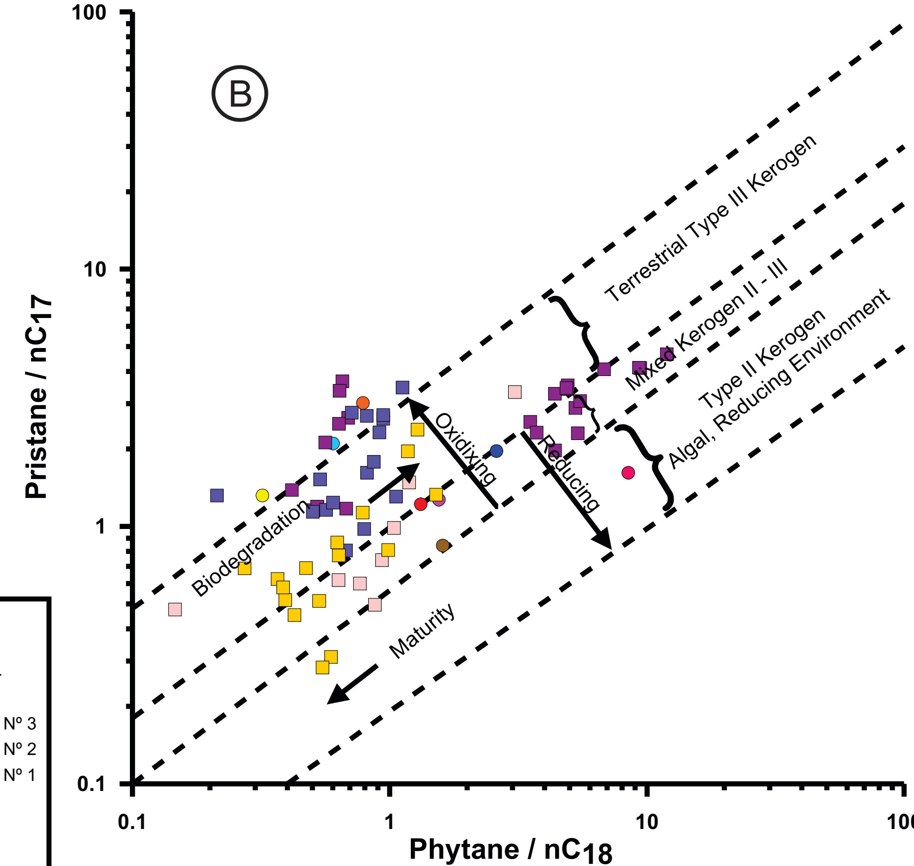
Compositional data from surface geochemistry samples indicate that most of the hydrocarbons are thermogenic, formed mainly during oil generation window with minor presence of high maturity hydrocarbons (gas generation window) (Figure A).

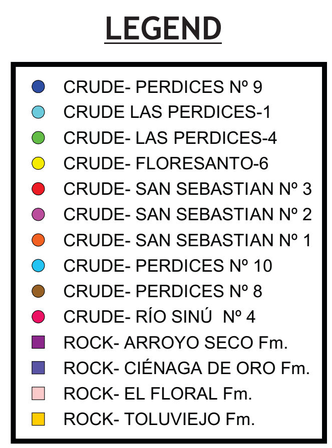
Isotopic data indicates thermogenic origin and mixing between different thermal maturity hydrocarbons is also indicated by the data (Figure B).

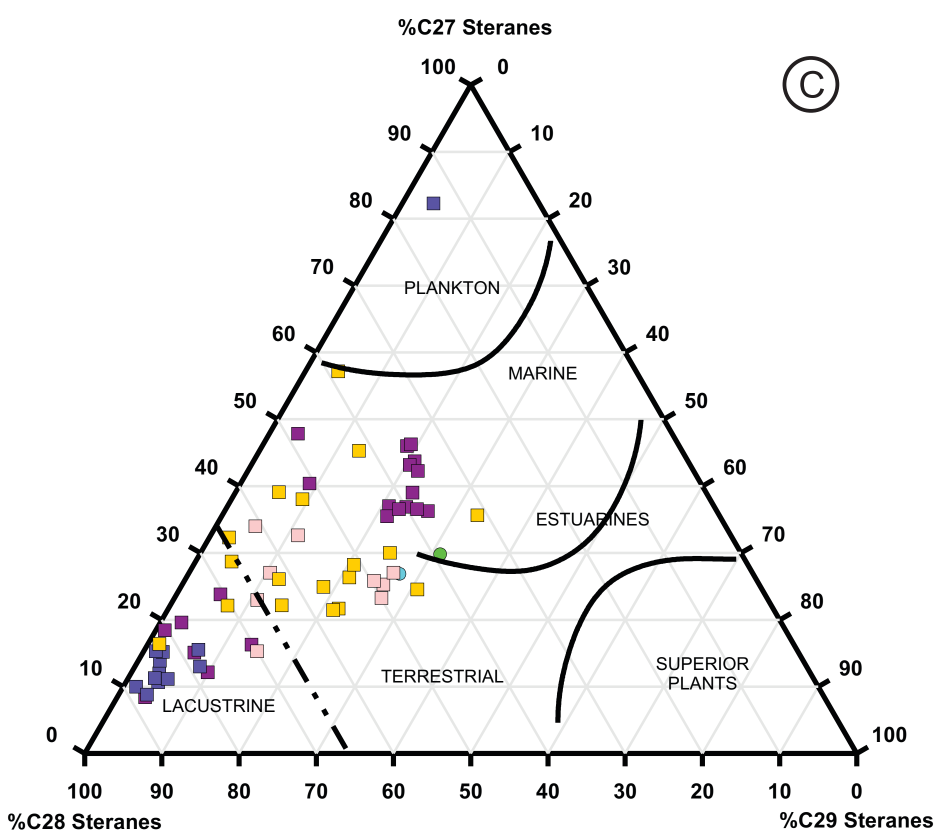
There are very few samples of microbial gas to consider biogenic gas an important process in the basin.

Petroleum Systems (Crude-Rock Correlations)







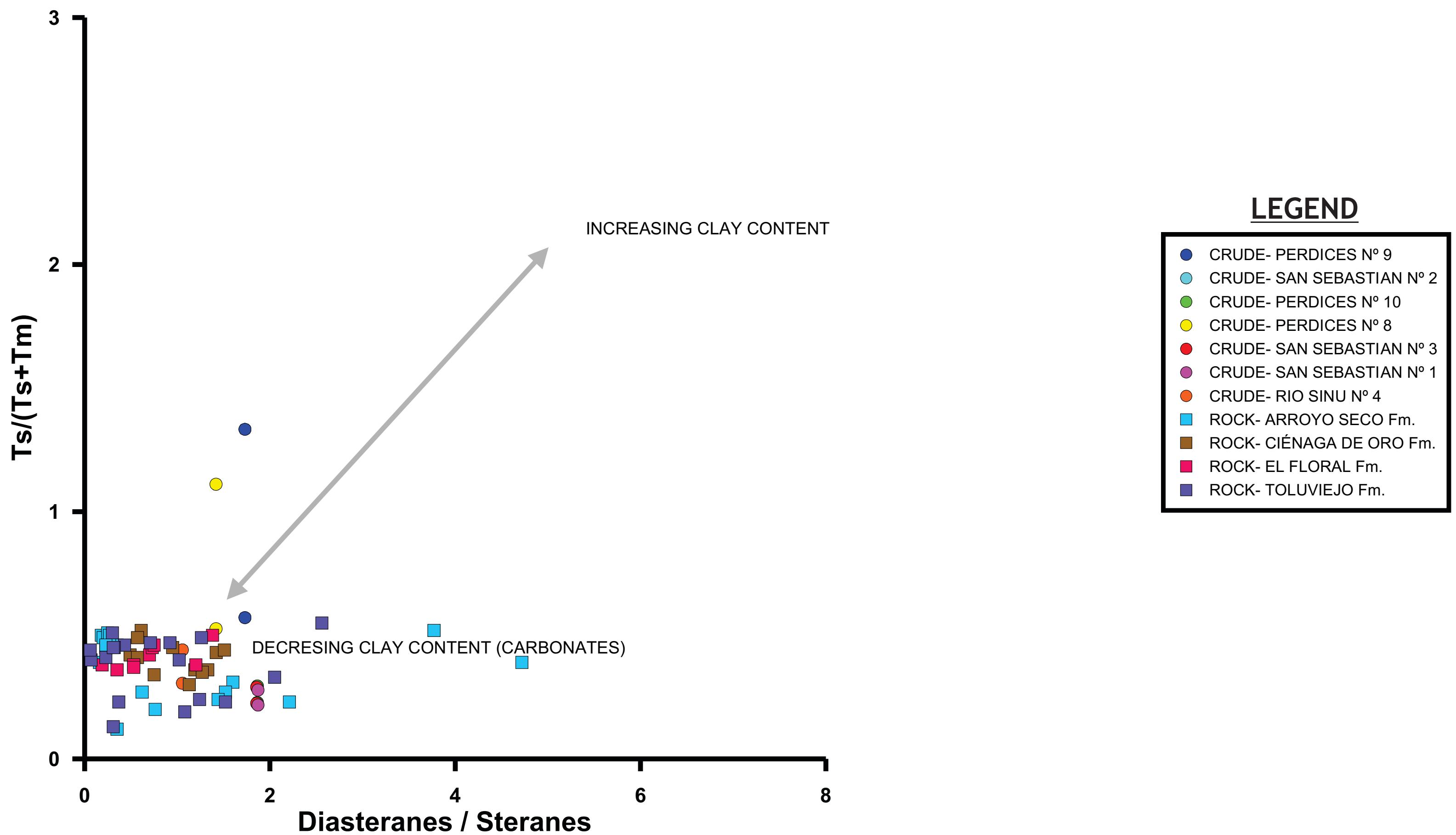


- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that oils from the San Sebastián-3, San Sebastián-2 and Río Sinú-4 wells have low oleanane index values (<0.2) and Pr/Ph values (<2), and correlate well with rock extracts from the Arroyo Seco Toluviejo and El Flora formationsl, suggesting that these units are the sources for the hydrocarbons found in those wells. The oil from the San Sebastián-1 well has higher Pr/Ph value (>4) and seems to correlate well with rock extracts from the Arroyo Seco Formation (Figure A).

- The Phytane/nC18 vs Pristane/nC17 graph shows good correlation between the crude oils found in the San Sebastián-1, San Sebastián-3, Perdices-10 and Floresanto-6 wells with rock extracts from samples of the Arroyo Seco, Ciénaga de Oro, El Floral and Toluviejo formations. Indicating that the oils have origin from terrestrial organic matter and to a minor extent from mixed kerogen (type II-III), but additionally that the crudes and rocks have similar thermal maturities (Figure B).

- The steranes ternary plot shows good correlation of crude oil from the Perdices-1 well with rock extracts from the El Floral formation, and that these rocks were deposited in an estuarine to lacustrine environment (Figure C).

Petroleum Systems (Crude-Rock Correlations)



The diasteranes/steranes vs Ts/(Ts+Tm) graph shows that the oils and rock extracts were generated from poor-clay rocks.

There is few crude and extracts information available for the basin, however some preliminary conclusions on the possible petroleum systems active at the basin can be obtained from this data.

- The extracts from the Tertiary formations (Arroyo Seco, Ciénaga de Oro, El Floral and Toluviejo) have low oleanane index values (< 0.2), indicative of low terrestrial organic matter input from angiosperms.

- Most of the crudes in the basin have high olenanane index values (> 0.4), and high values of this index are indicative of high terrestrial organic matter input and/or Tertiary age of the source rocks (Peters and Moldowan, 1993).

- Some crude oils correlate with the low oleanane extracts of the Tertiary formations, suggesting that these units could be the sources for those oils, particularly those with Pristane/Phytane < 2 (Arroyo Seco and El Floral formations).

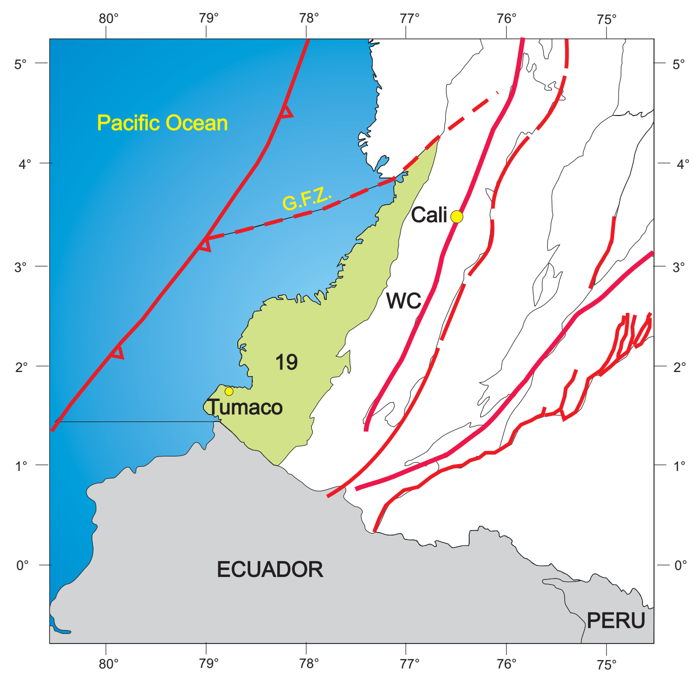
- From the existing information at the basin some hypothetical petroleum systems can be postulated: Arroyo Seco (.), Arroyo Seco –Chengue (.), Arroyo Seco – Toluviejo (.), Arroyo Seco – Ciénaga de Oro (.), Toluviejo (.), Toluviejo – Chengue (.), Toluviejo – Ciénaga de Oro (.), Ciénaga de Oro (.).

TUMACO BASIN

Generalities
Wells and Seeps
Source Rock Characterization

Generalities

TUMACO BASIN
LOCATION AND BOUNDARIES



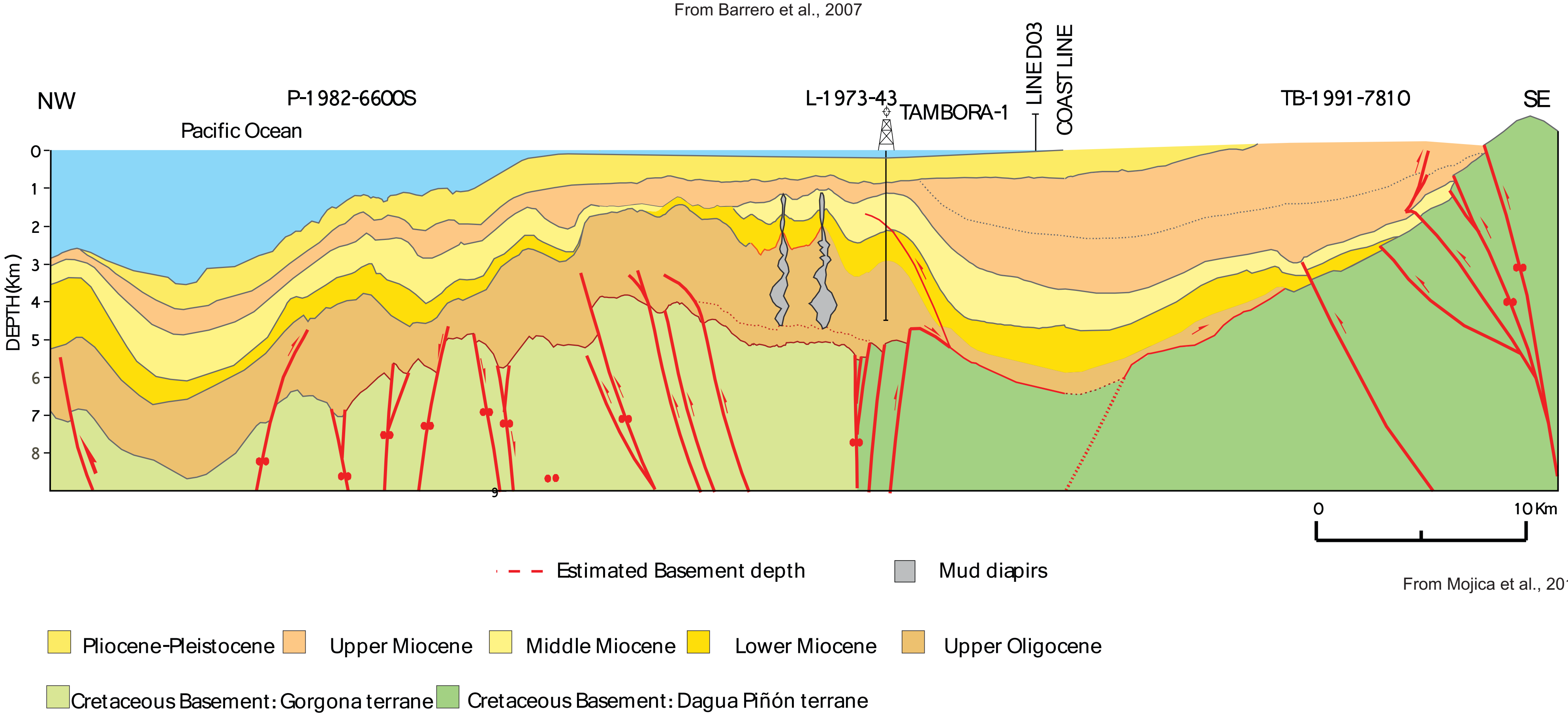
BOUNDARIES

North: Garrapatas fault zone (G.F.Z.)
East: Western Cordillera (WC) Volcanic rocks
South: Colombian-Ecuadorian border
West: Coast line of the Pacific Ocean

From Barrero et al., 2007

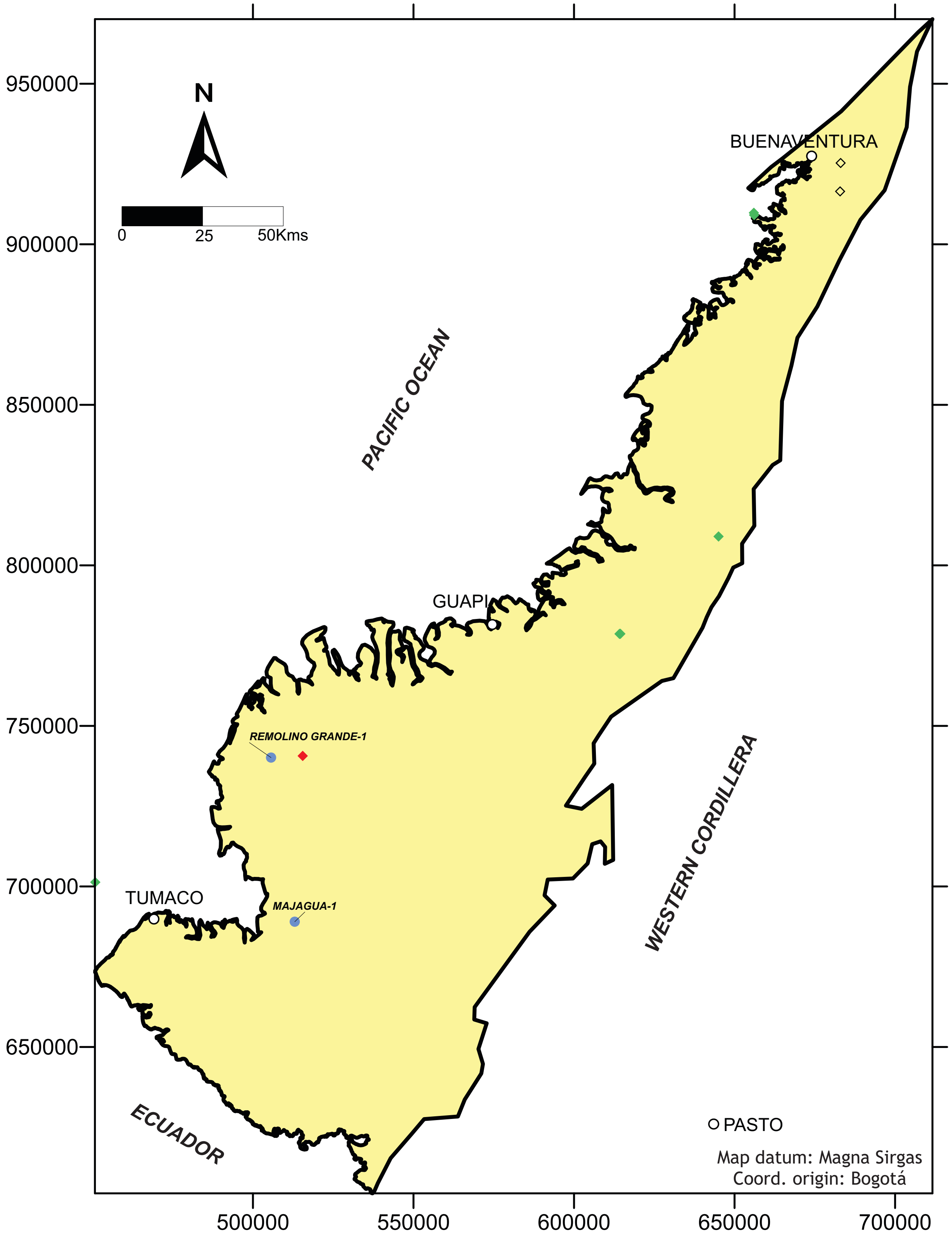
The source rock geochemical information interpreted for the Tumaco Basin includes %TOC and Rock-Eval Pyrolysis data from 94 samples taken in 2 locations; additionally 64 organic petrography samples from 2 locations were interpreted.

Due to the lack of crude oil geochemical data, crude oil interpretation was not made for the basin.



From Mojica et al., 2010

Wells and Seeps

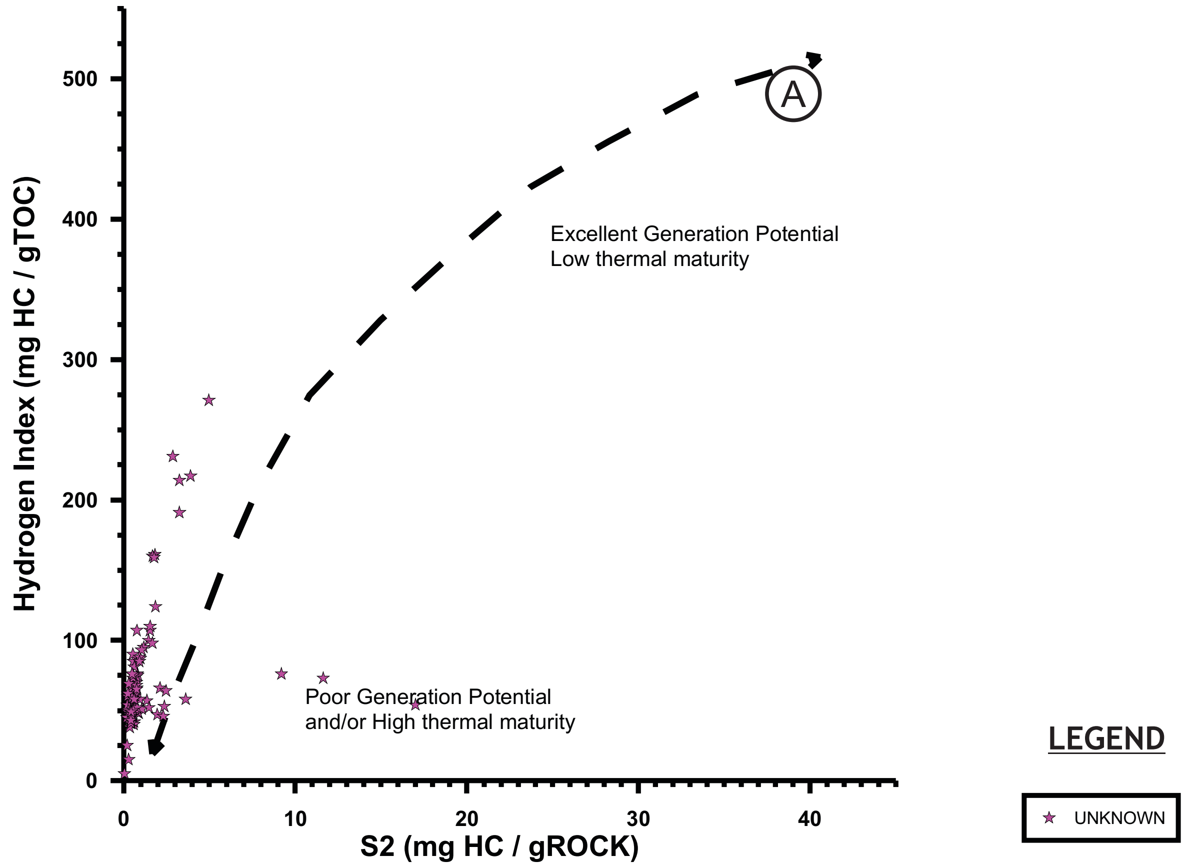


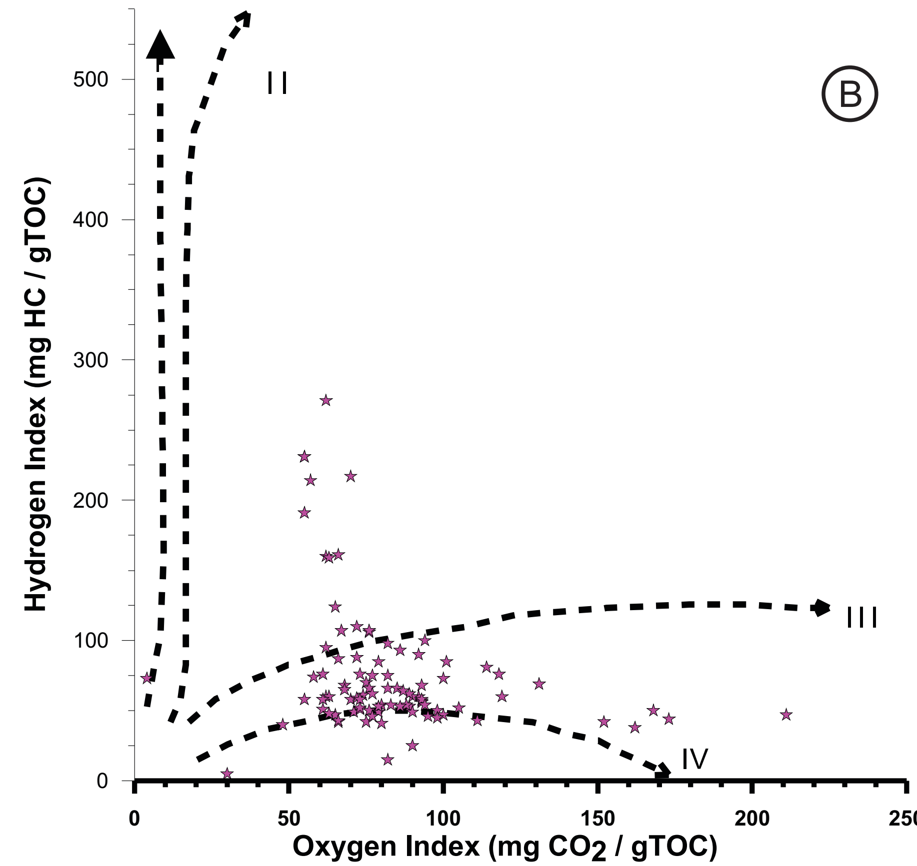
The number of wells and/or surface locations with geochemical information in the Tumaco Basin is 2.

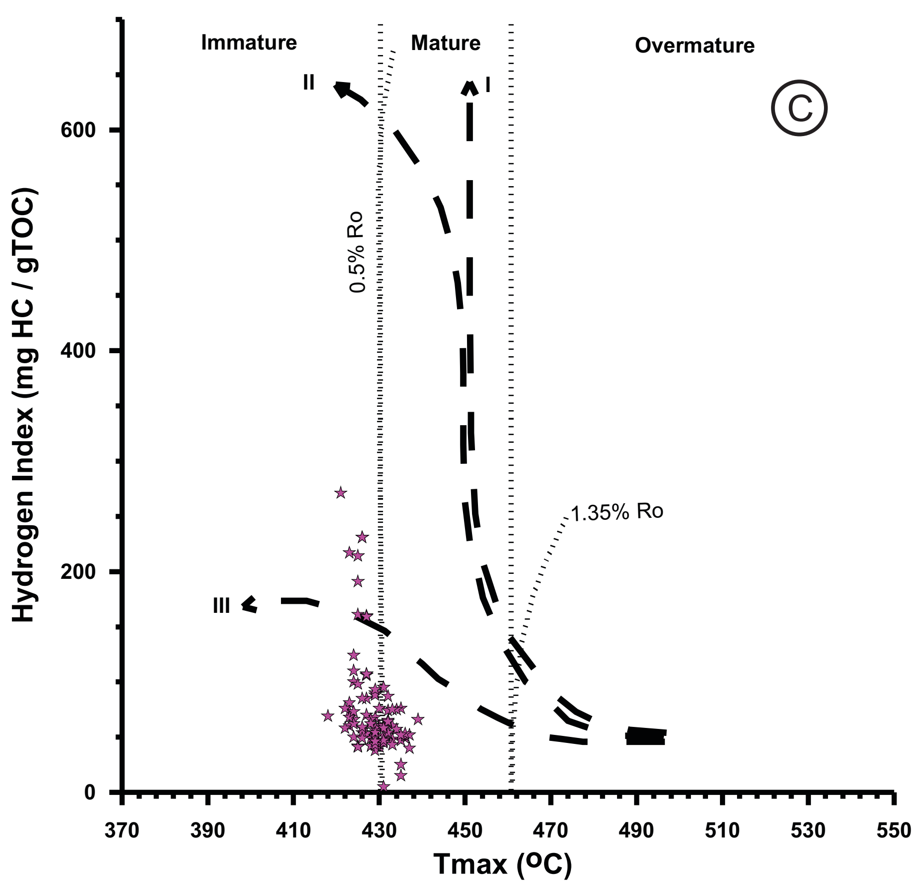
There are five seeps reported in the basin.

- Wells with geochemical information
- Oil seeps
- Gas seeps
- Undetermined seeps
- Cities/Towns

Source Rock Characterization





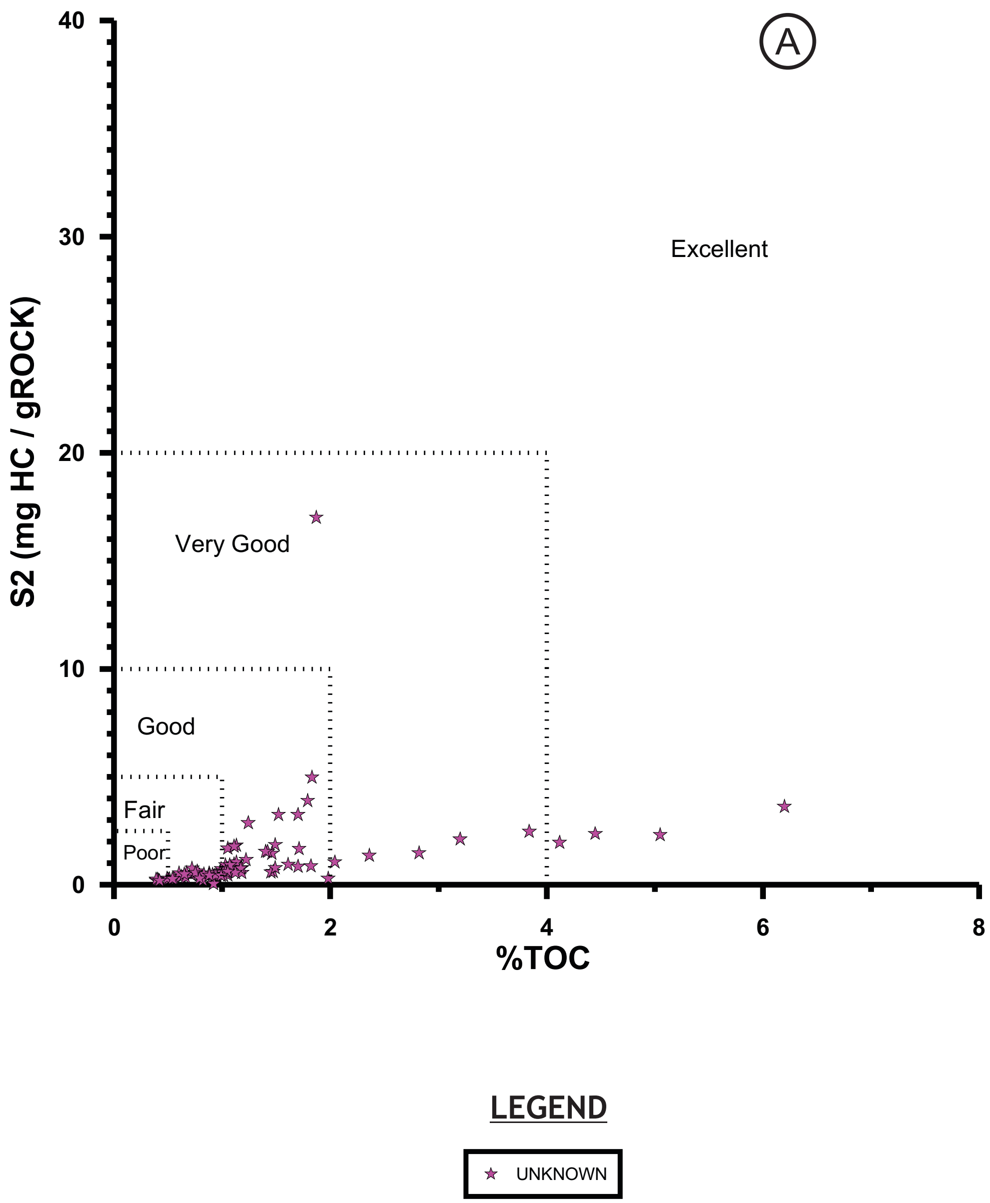


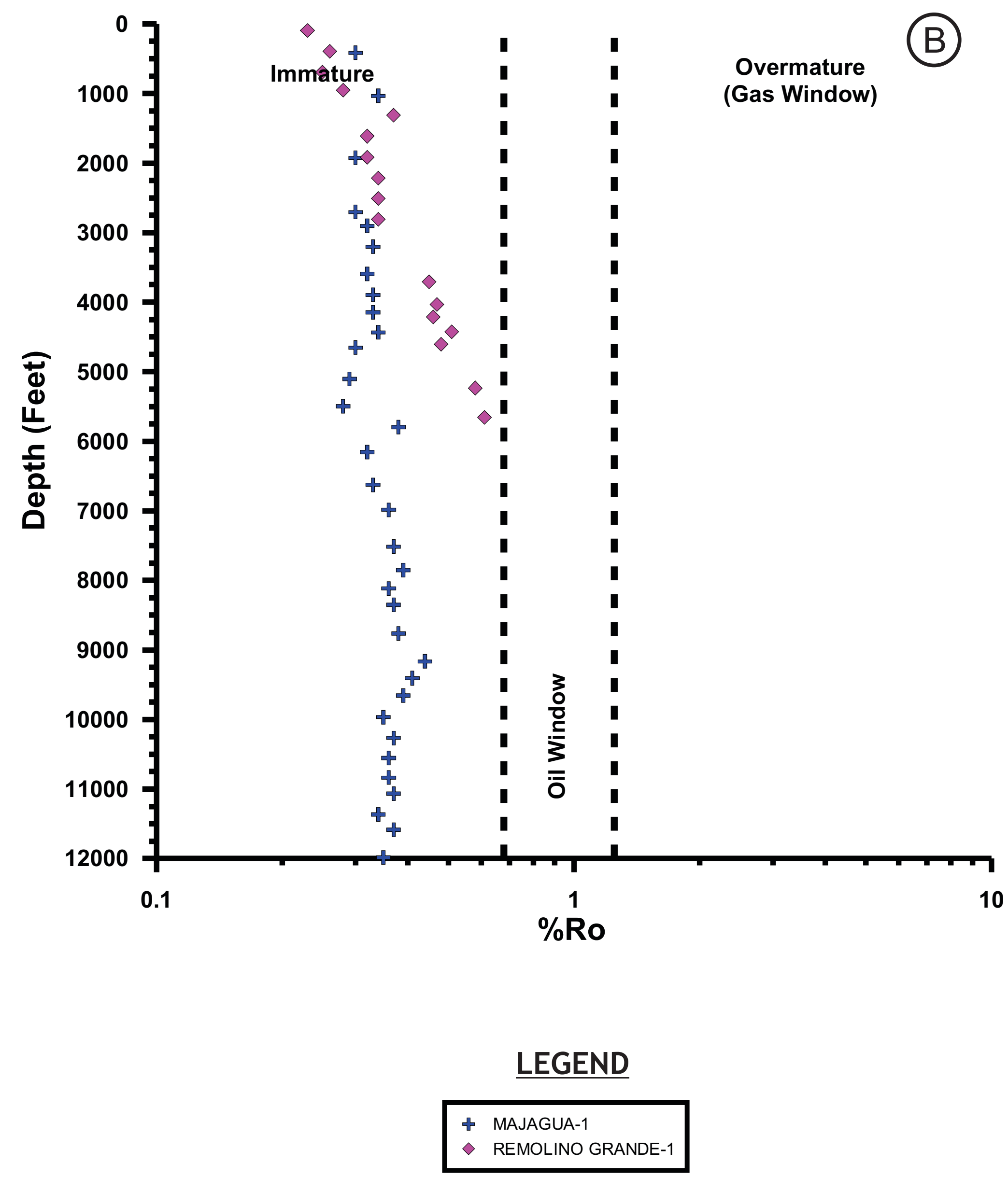
- The data obtained from pyrolysis Rock-Eval of rock samples for Hydrogen Index (HI) and S2 peak, indicate that the potential source rocks in the basin have poor generation potential (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock) (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples have type III gas-prone kerogen to type IV kerogen, with some samples with higher Hydrogen Index, indicative of a type II-II kerogen (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that samples in the basin have reached early maturity conditions (Figure C).

Source Rock Characterization





- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, the graph shows that the samples have good to excellent organic matter contents (%TOC) but fair to poor S2 values, indicating that the labile fraction of the kerogen is small and generation of important volumes of liquid hydrocarbons from these rocks might be not very likely (Figure A).

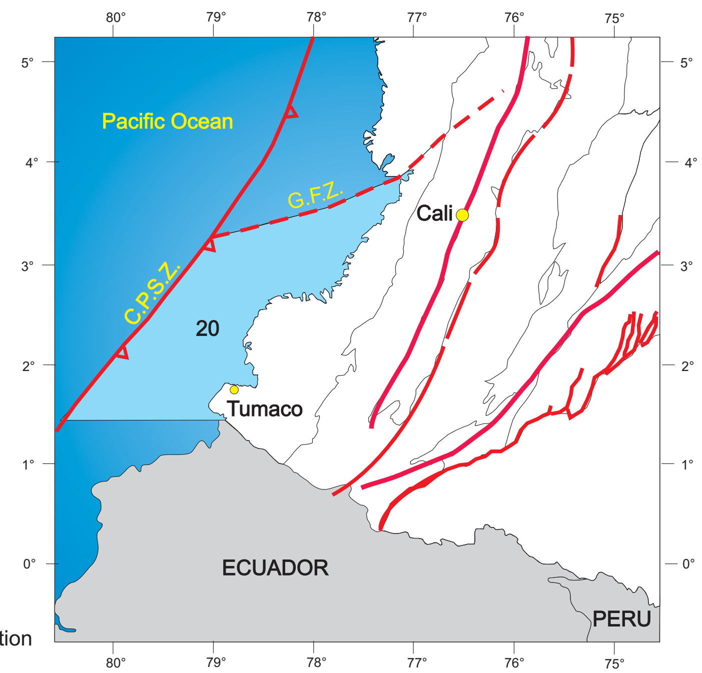
-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence is immature or close to early maturity in the basin. (Figure B).

TUMACO OFFSHORE BASIN

Generalities
Wells and Seeps
Source Rock Characterization

Generalities

TUMACO OFFSHORE BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

North: Garrapatas fault zone (G.F.Z.)
East: Present shoreline
South: Colombian-Ecuadorian border
West: Trench of the Colombian Pacific subduction zone (C.P.S.Z.)

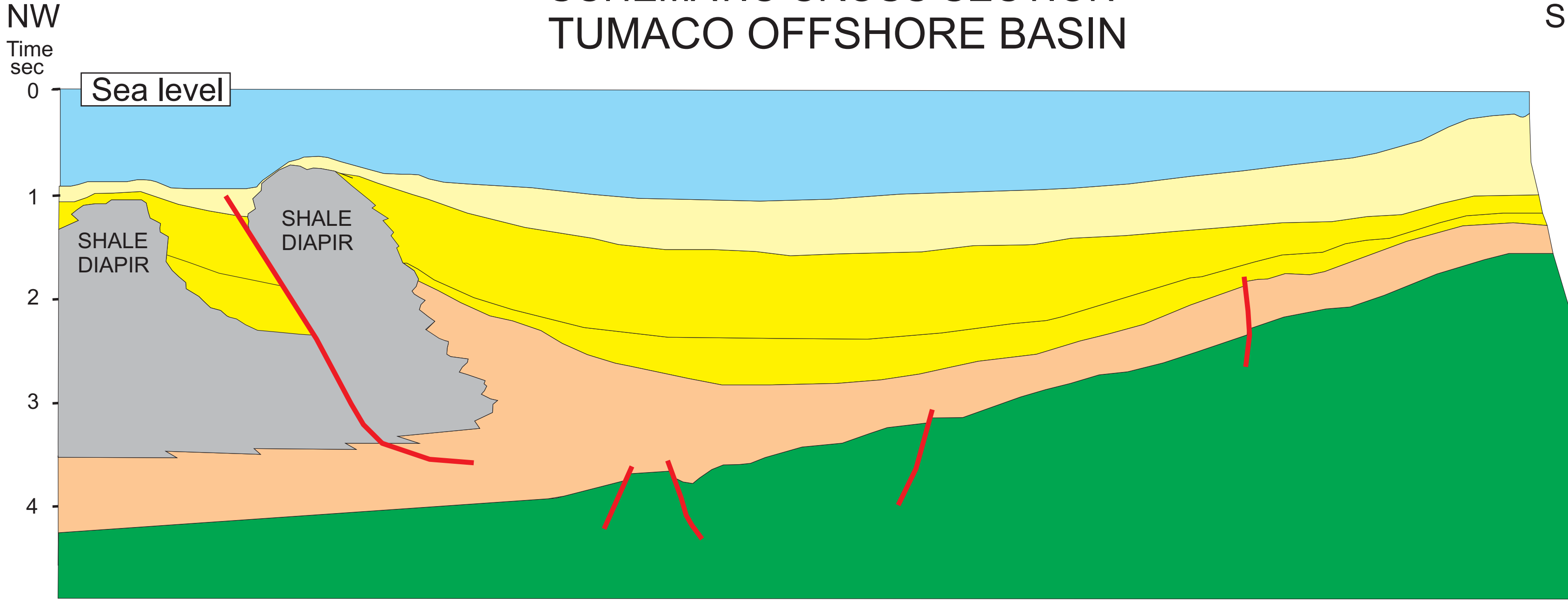
From Barrero et al., 2007

The source rock geochemical information interpreted for the Tumaco Offshore Basin includes %TOC and Rock-Eval Pyrolysis data from 22 samples taken in 2 locations; additionally 23 organic petrography samples from 2 locations were interpreted.

Due to the lack of crude oil geochemical data, crude oil interpretation was not made for the basin.

SCHEMATIC CROSS SECTION
TUMACO OFFSHORE BASIN

NW SE

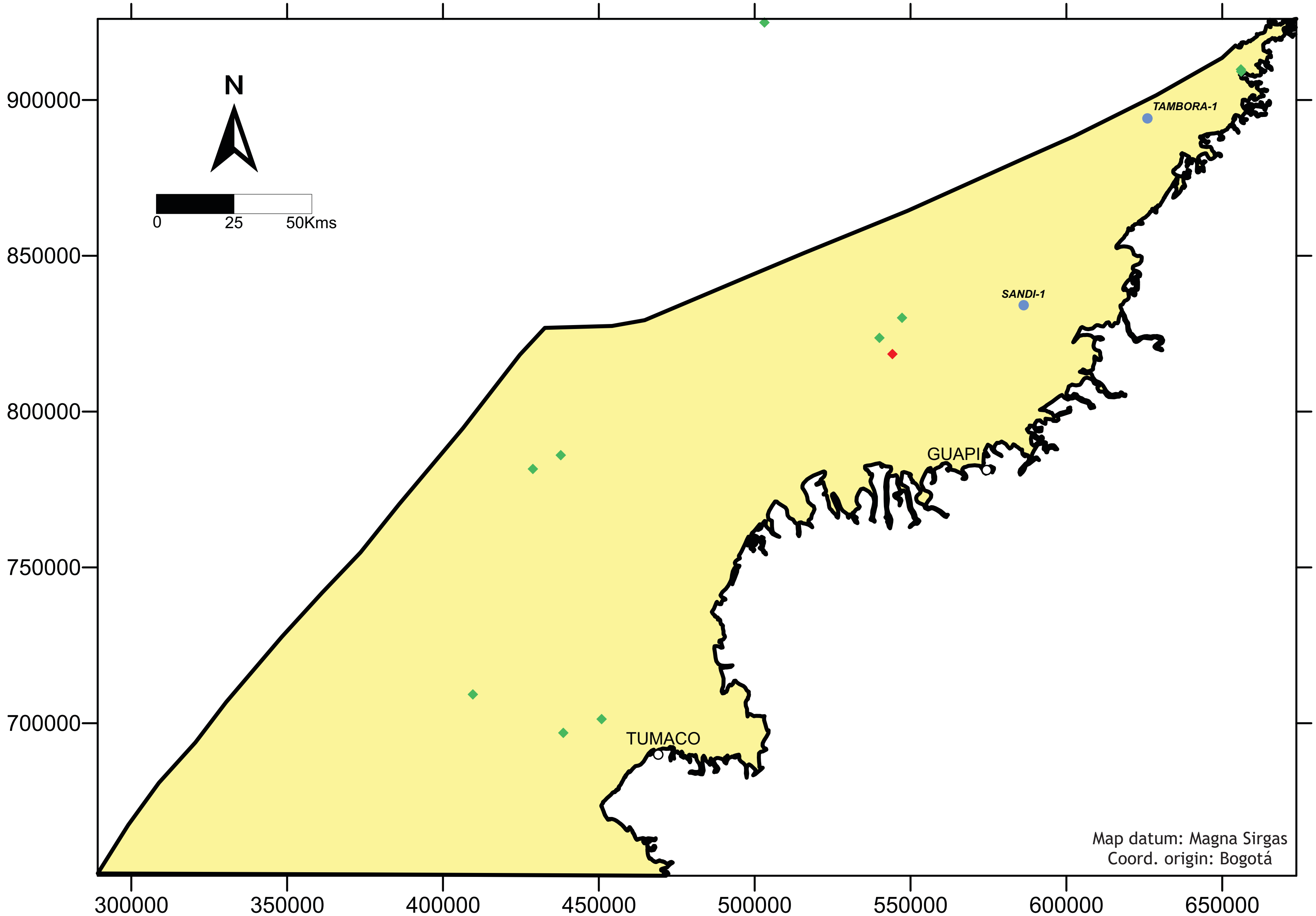


Color code according to the commission for the Geological Map of the World (2005)

Oceanic Crust Paleogene Neogene

From Barrero et al., 2007

Wells and Seeps

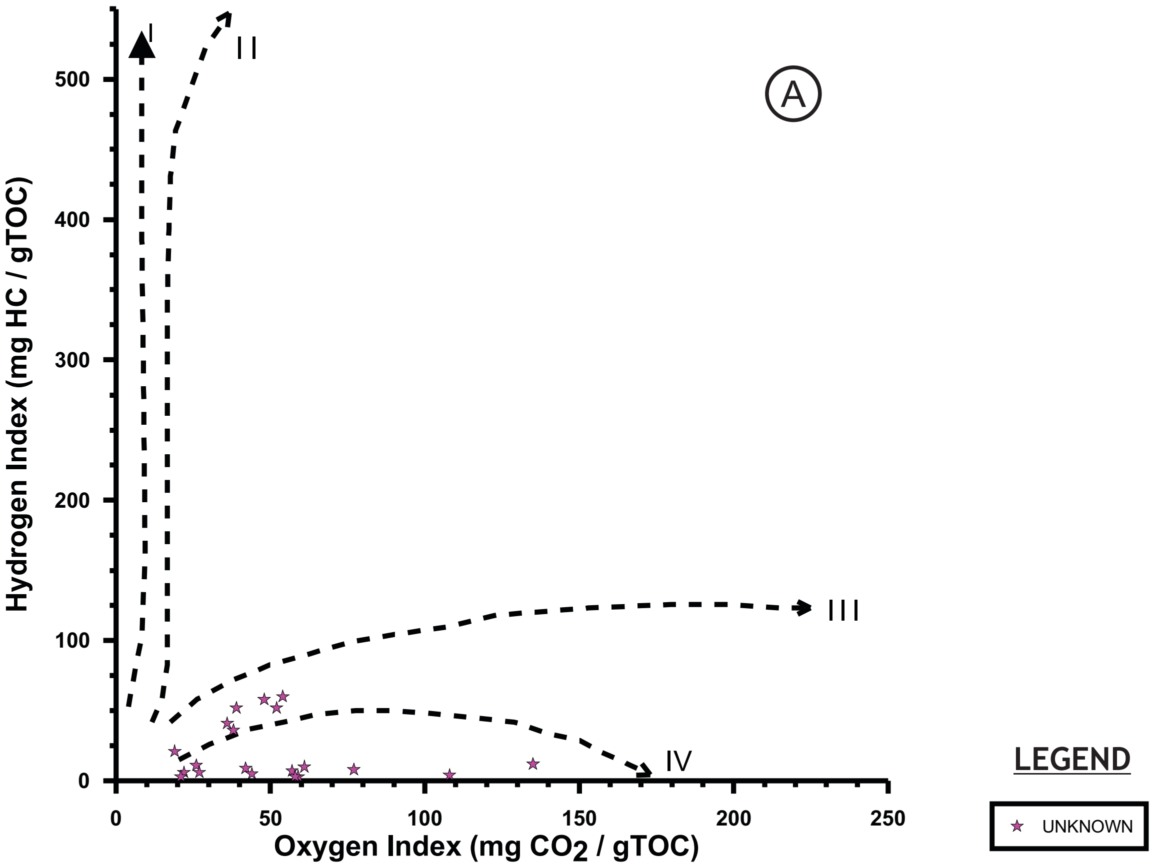


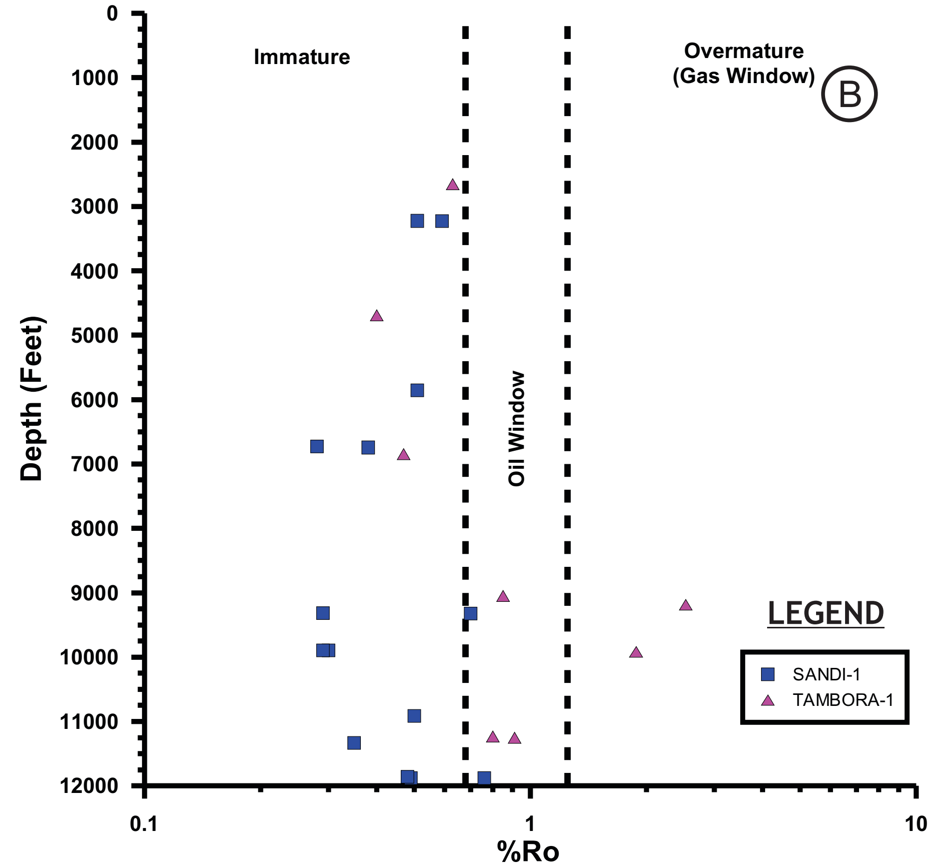
- Wells with geochemical information
- Oil seeps
- Gas seeps
- Cities/Towns

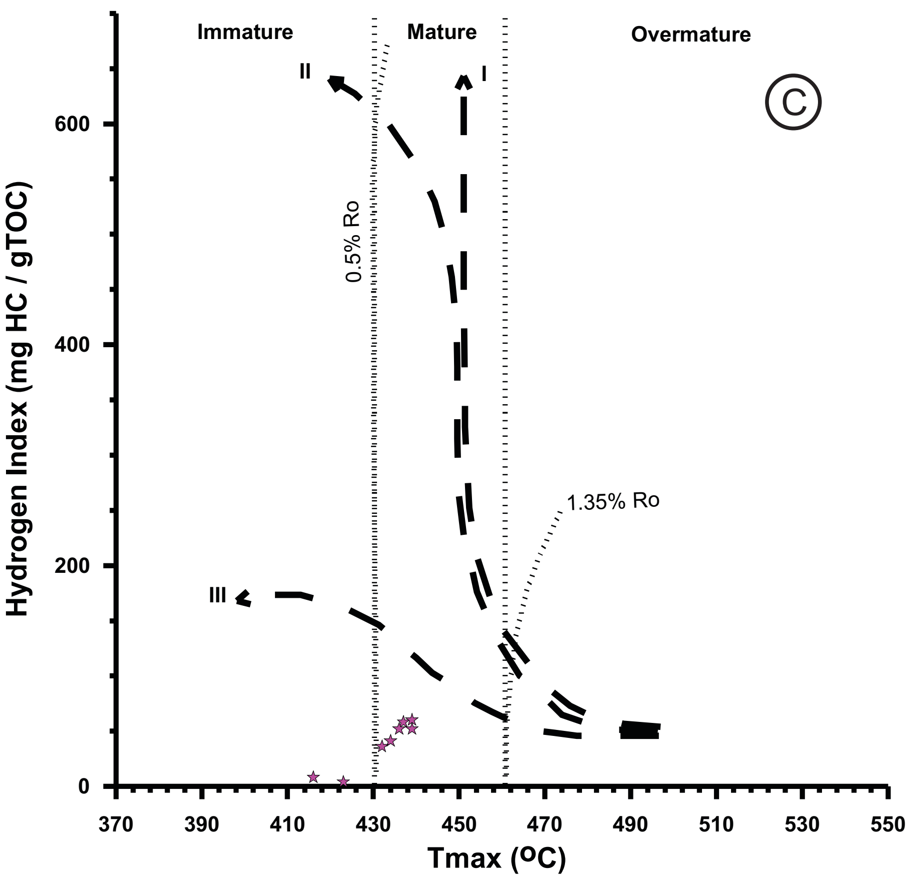
The number of wells and/or surface locations with geochemical information in the Tumaco Offshore Basin is 2.

There are nine seeps reported in the basin.

Source Rock Characterization







- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that the rock samples taken in the basin are indicative of type III gas-prone kerogen to type IV kerogen (Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence is immature to early mature in the basin. There are two samples overmature off trend in the Tambora-1 well (Figure B).

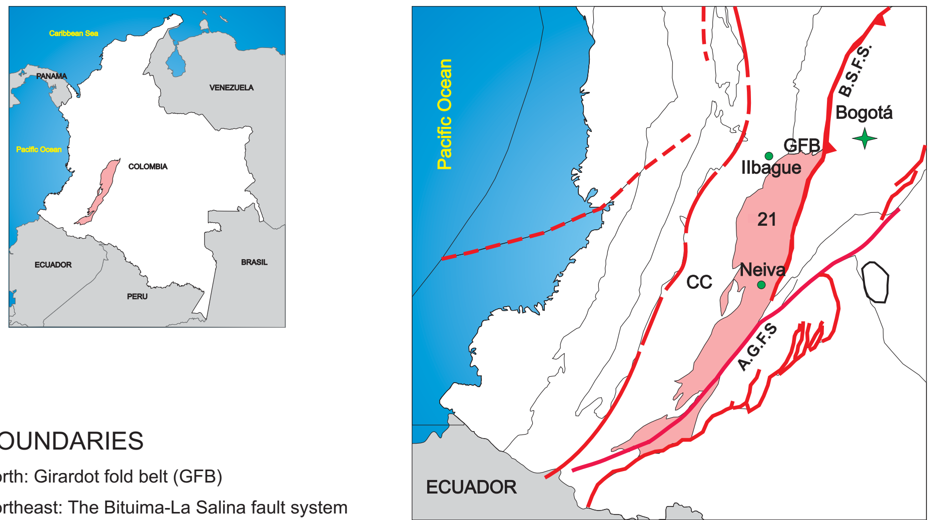
- The Tmax maturity parameter vs Hydrogen Index graph shows that the samples, have reached early maturity conditions in the basin, in agreement with the %Ro data. (Figure C).

UPPER MAGDALENA VALLEY BASIN

Generalities
Wells and Seeps
Crude Oil Quality
Depositional Environments
Chromatography
Source Rock Characterization
Source Rock Quality and Maturity Maps
Gas Characterization
Surface Geochemistry
Petroleum Systems (Crude-Rock Correlations)

Generalities

UPPER MAGDALENA VALLEY BASIN
LOCATION AND BOUNDARIES



BOUNDARIES

North: Girardot fold belt (GFB)

Northeast: The Bituima-La Salina fault system (B.S.F.S.)

Southeast: Partially the Algeciras-Garzón fault system (A.G.F.S.)

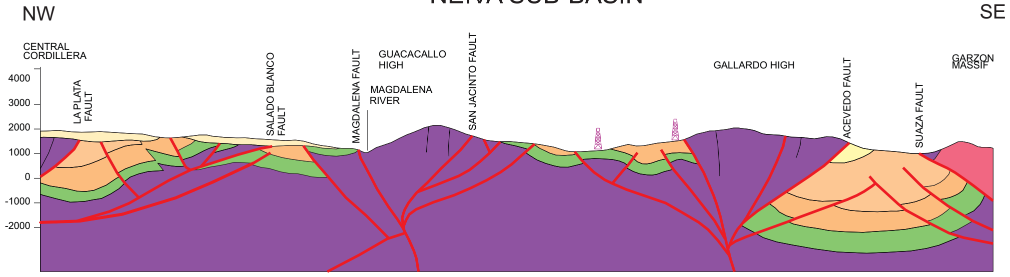
West: Pre-cretaceous rocks of the Central Cordillera (CC)

From Barrero et al., 2007

The source rock geochemical information interpreted for the Upper Magdalena Valley Basin includes %TOC and Rock-Eval Pyrolysis data from 3163 samples taken in 54 wells; additionally 827 organic petrography samples from 43 wells were interpreted.

Crude oil and extracts information from 142 bulk analysis samples, 585 liquid chromatography samples, 1026 gas chromatography samples, 428 biomarker samples, 234 isotopes samples and 379 surface geochemistry samples were also interpreted.

NEIVA SUB-BASIN

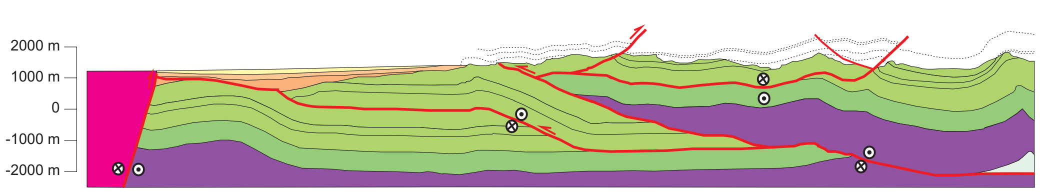


Taken from Fabre, 1995

Color code according to the commission for the Geological Map of the World (2005)

Precambrian | Jurassic | Cretaceous | Paleogene | Neogene

GIRARDOT SUB-BASIN

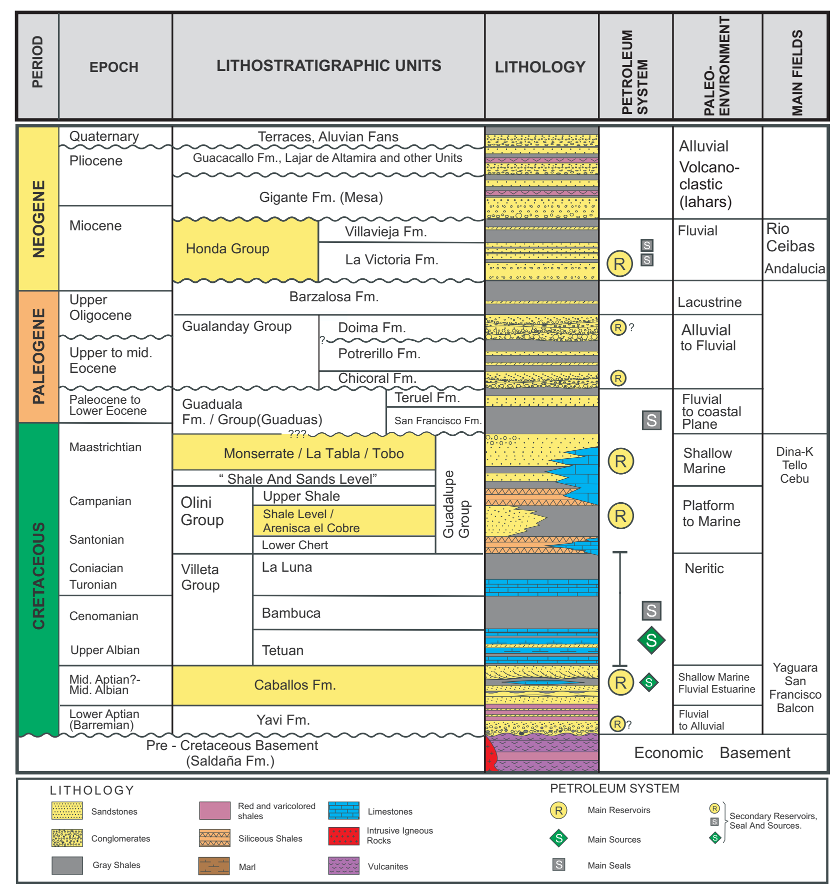


Taken from Montes, 2001

Color code according to the commission for the Geological Map of the World (2005)

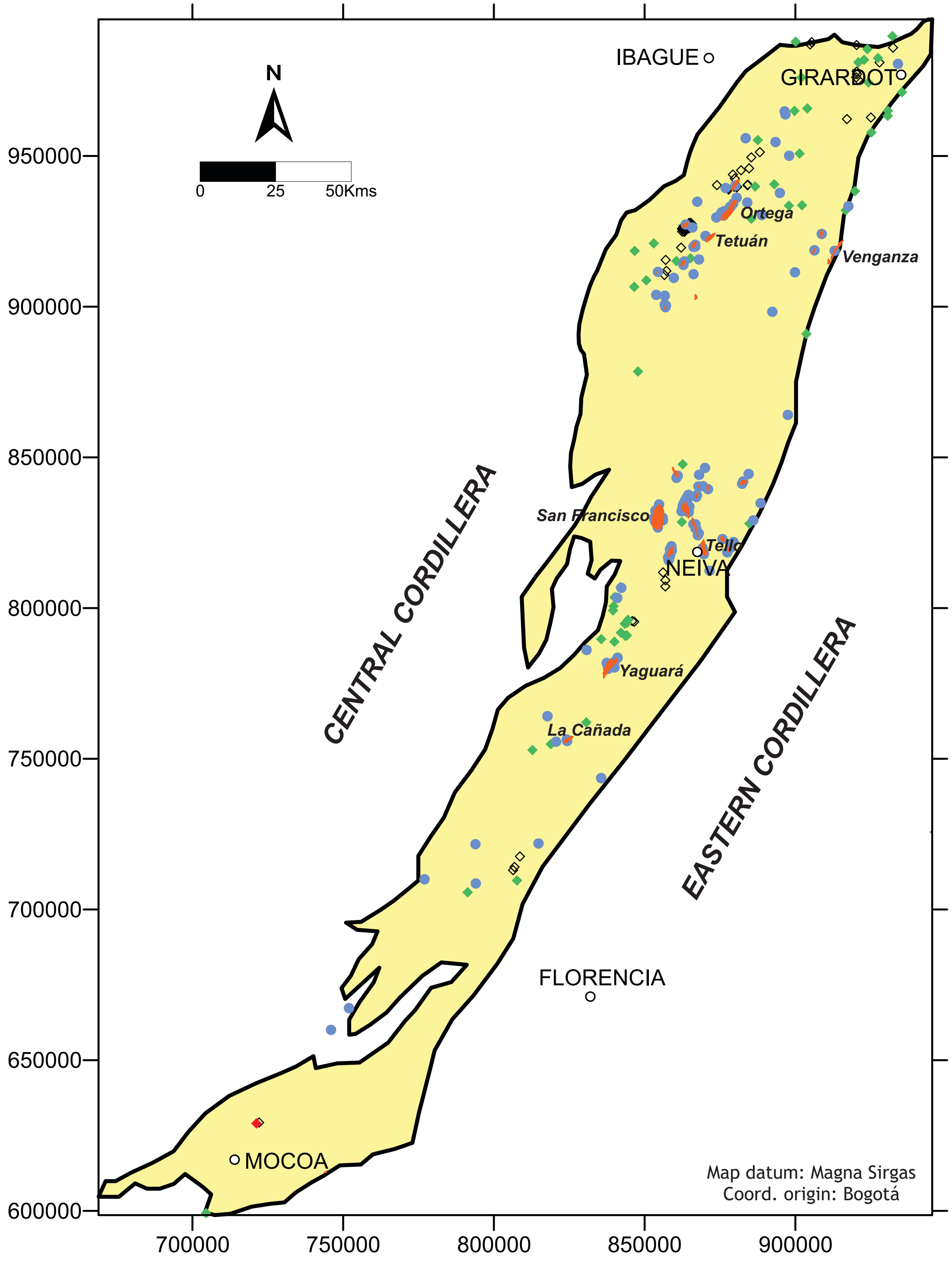
Metamorphics | Paleozoic | Triasic-Jurassic | Lower Cretaceous | Upper Cretaceous | Paleogene | Neogene

From Barrero et al., 2007



From Mora, J.A., 2003

Wells and Seeps

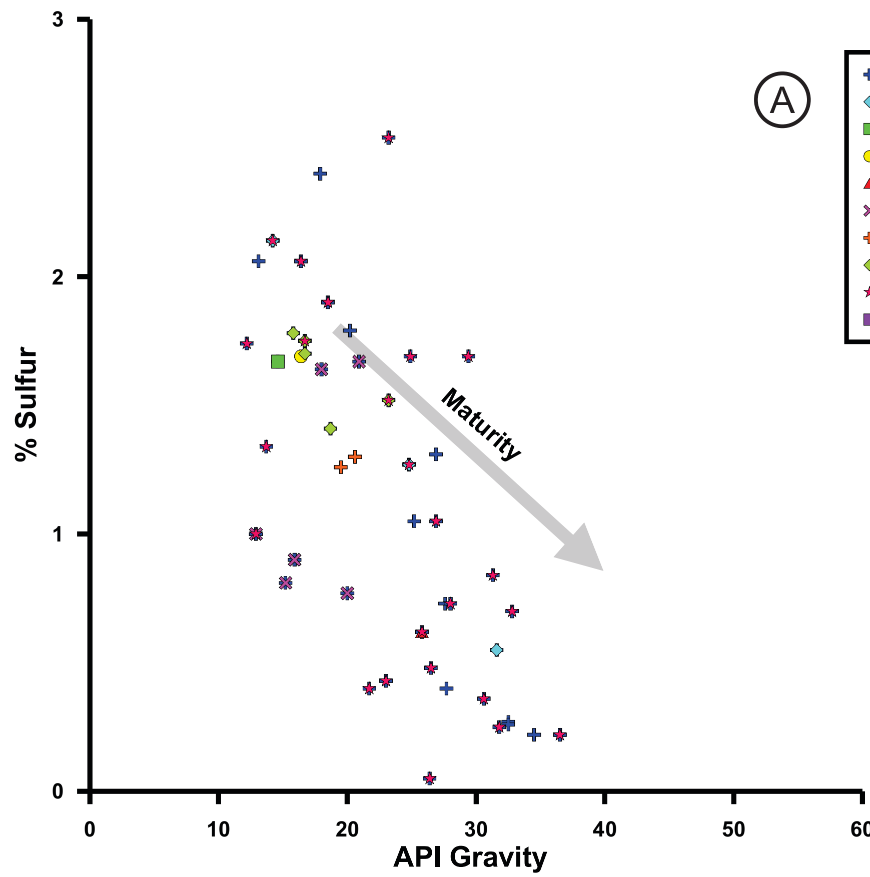


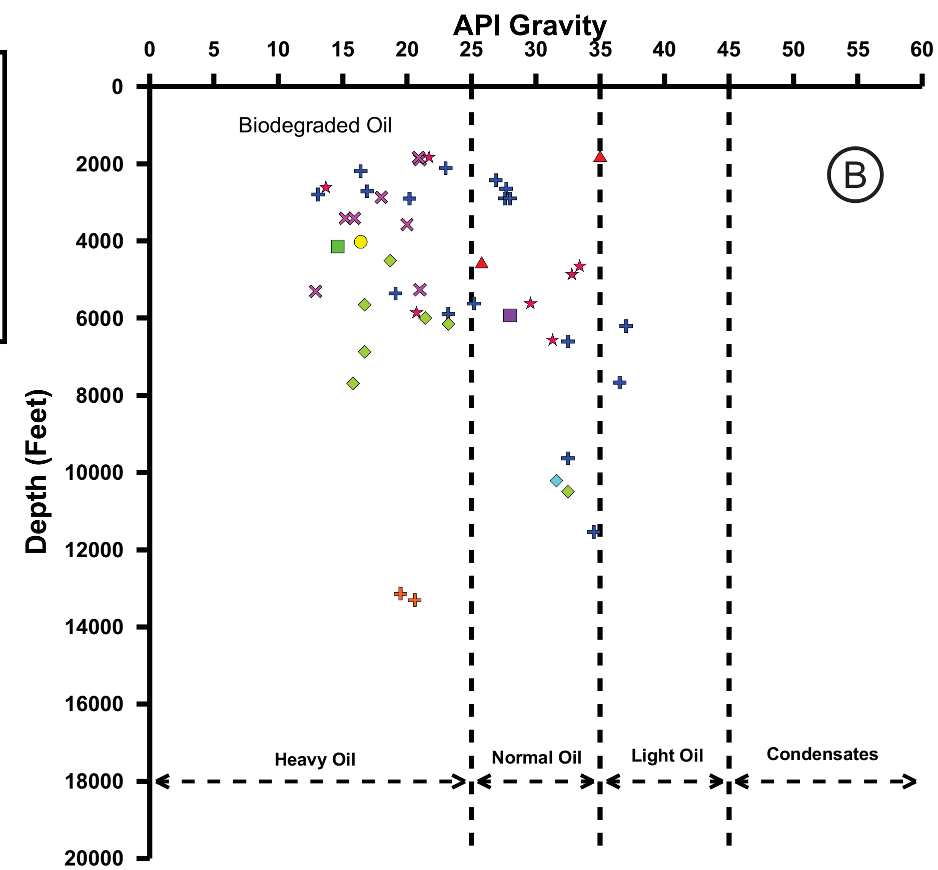
The number of wells and/or surface locations with geochemical information in the Upper Magdalena Valley Basin is 192.

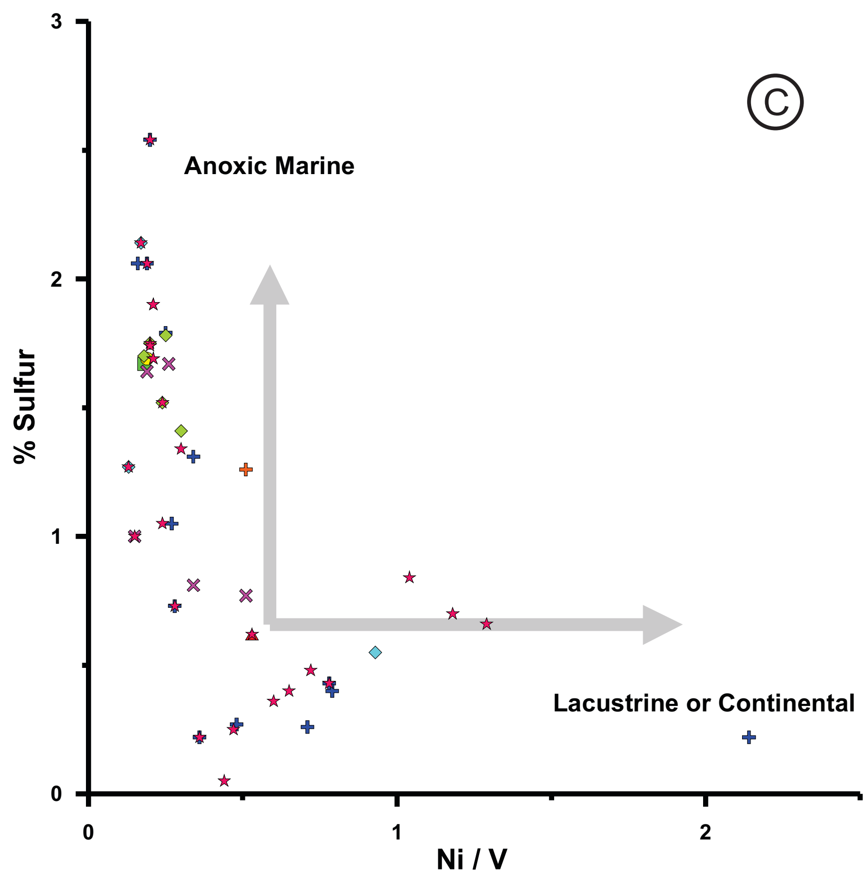
Oil seeps are mainly located in the northern and central parts of the basin.

- Oil and gas fields
- Wells with geochemical information
- Oil seeps
- Gas seeps
- Undetermined seeps
- Cities/Towns

Crude Oil Quality





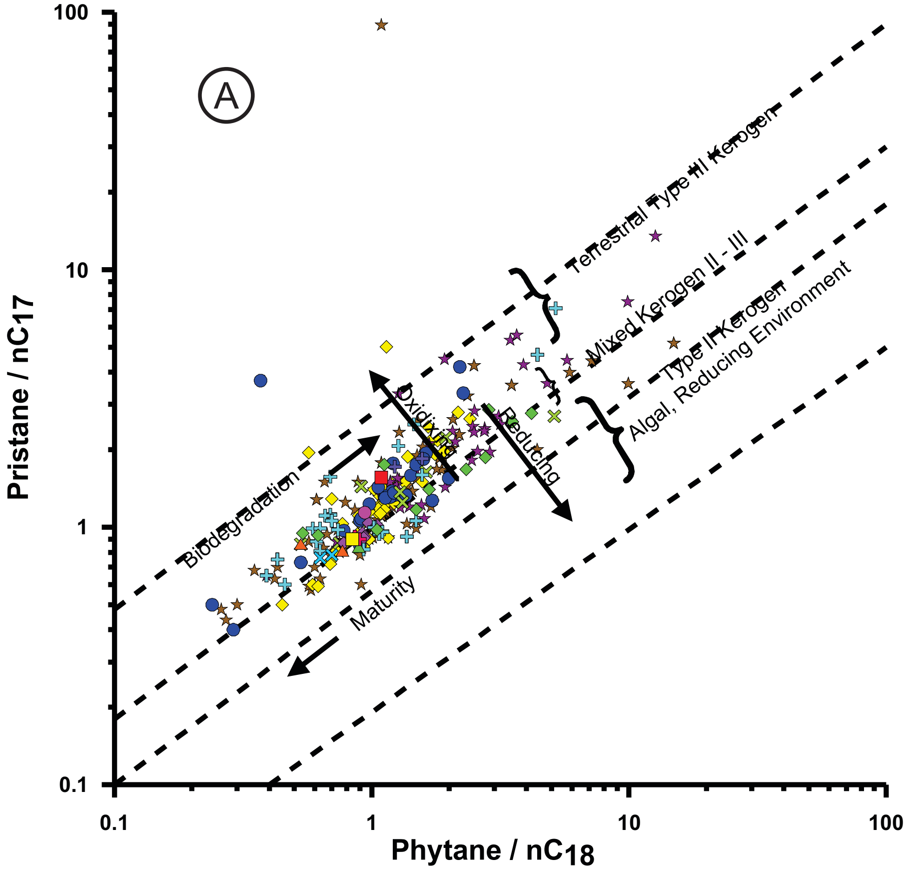


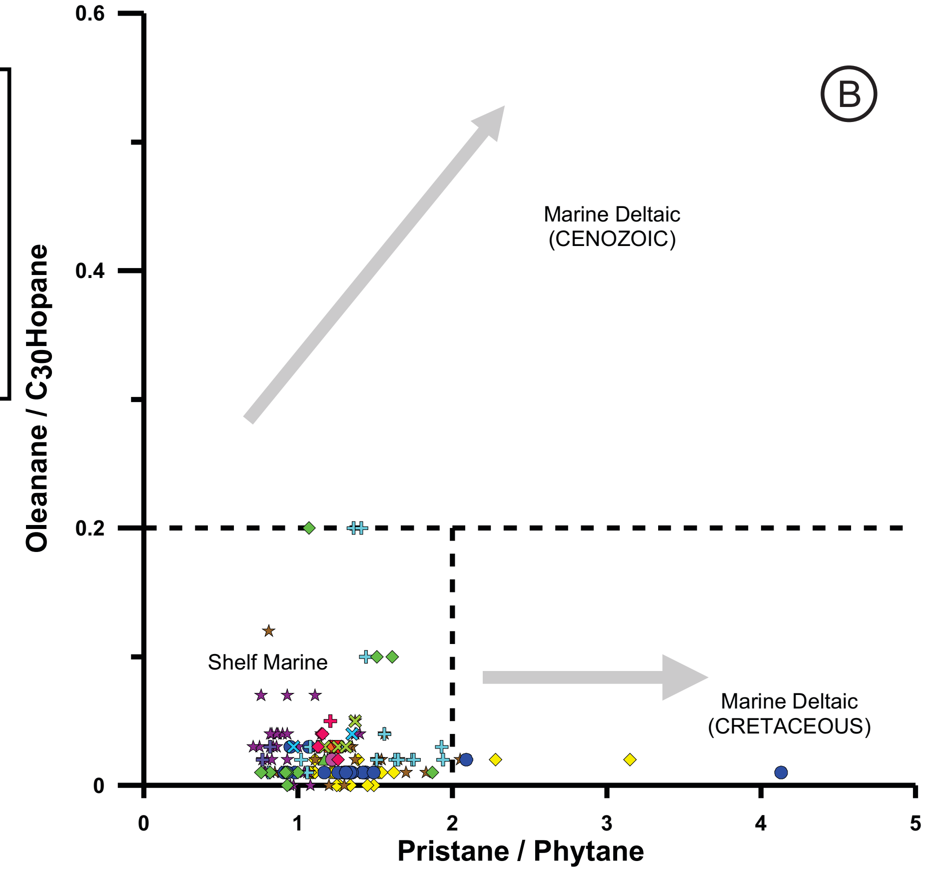
Heavy to light oils with API gravities ranging from 10° to 40° and sulfur content between 0 and 3% are present in the basin. There is no straight relationship between sulfur and API gravity, but there is a progressive decrease in sulfur content as API gravity increases. This suggests that in the basin there are oils with different thermal maturities,the more mature have higher API gravity and lower sulfur content; but there are also crudes that having similar API gravities have different sulfur contents, which might indicate biodegradation, increasing sulfur content, and/or different source rocks, considering that oils sourced from shales usually have lower sulfur content than oils from carbonates (Figure A).

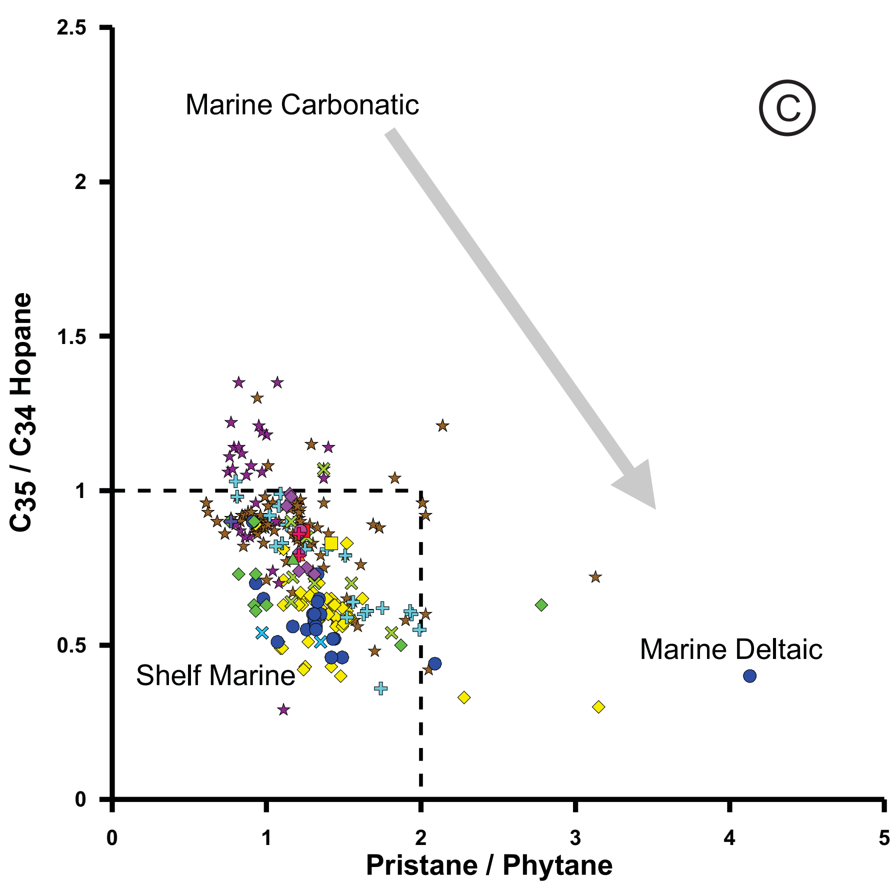
- There is no direct relationship between depth and crude oil quality, indicating that similar quality oils can be found at different stratigraphic levels, probably related to vertical migration in faulted reservoirs. But additionally there is the fact that different API gravity oils can be found at similar depths, reflecting different preservation (biodegradation) and/or thermal maturities (Figure B).

- The sulfur content of most crude oils is lower than 2%, and its Ni/V ratio below 0.5, suggesting that they are produced from rocks deposited in a marine suboxic environment with low terrigenous organic matter input (Figure C).

Depositional Environments





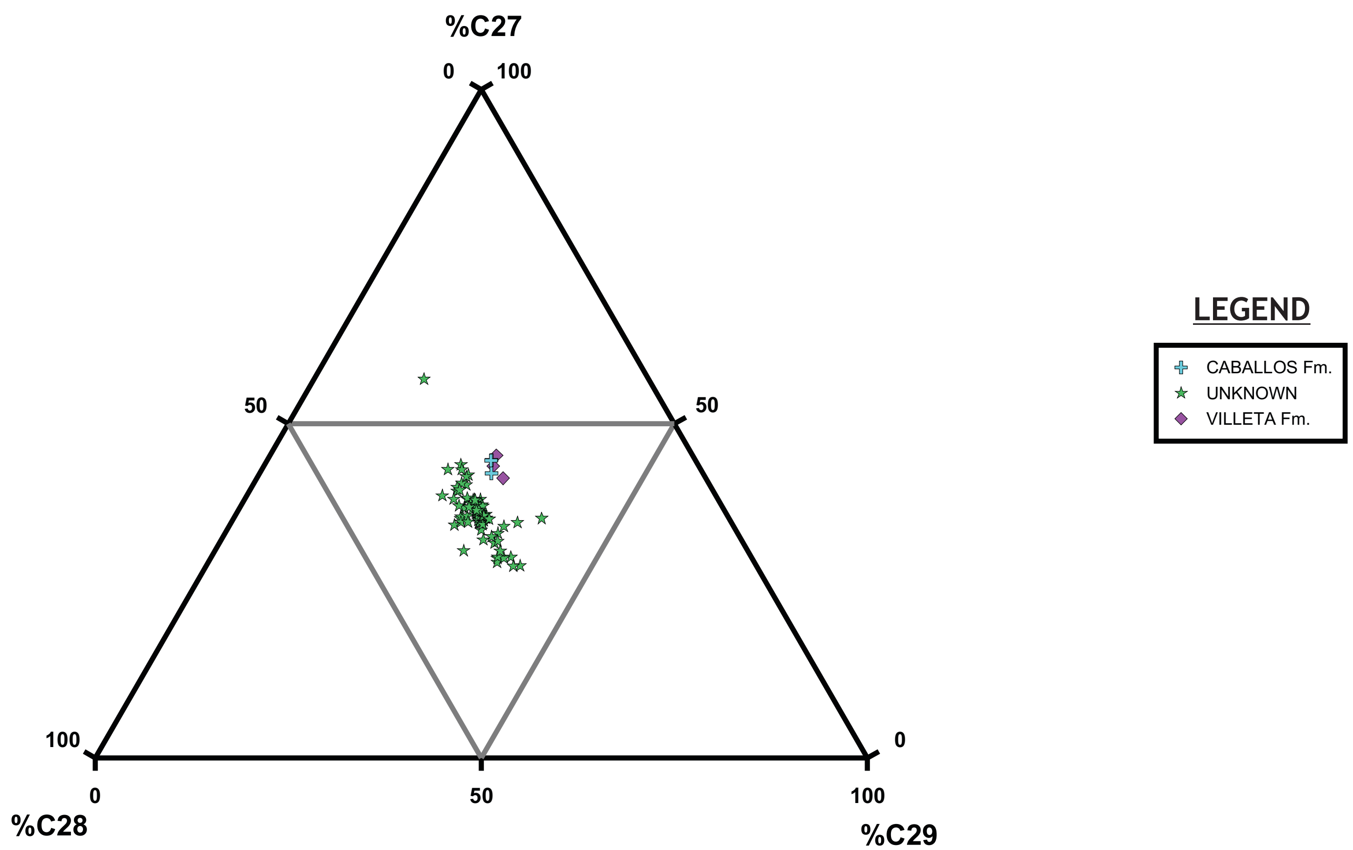


- The Phytane/nC18 vs Pristane/nC17 graph indicates that most of the oils have origin from terrestrial organic matter (Type III kerogen) deposited in an oxidizing environment and have suffered low biodegradation. There are also some samples in the mixed kerogen range, suggesting a source rock with terrestrial and marine organic matter (Type II and III kerogens) deposited in more reducing conditions (Figure A). The data also suggests variable preservation of the crude oils (biodegradation).

- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that most of the oils have low oleanane index values (<0.2) and Pr/Ph values (<2) which indicates that these oils are generated from source rocks deposited in shelf marine environments. There are some samples with low oleanane index values but high Pr/Ph (>2) indicating that these oils were generated from source rocks deposited in marine deltaic environments. The oleanane index has been also used as an age indicator of the source rock, with high oleanane values for oils generated in Cenozoic rocks and low oleanane values in oils from older rocks (Figure B).

- The Pristane/Phytane vs C35/C34 Hopane (Homohopane index) graph shows that most oil samples have Pr/Ph values below 2 and C35/C34 Hopane below 1, indicating that these oils were generated from siliciclastic rocks deposited in a shelf marine environment. Additionally there are some samples with low homohopane index but higher Pr/Ph values (>2) indicative of siliciclastic rocks deposited in marine deltaic environments (Figure C).

Depositional Environments



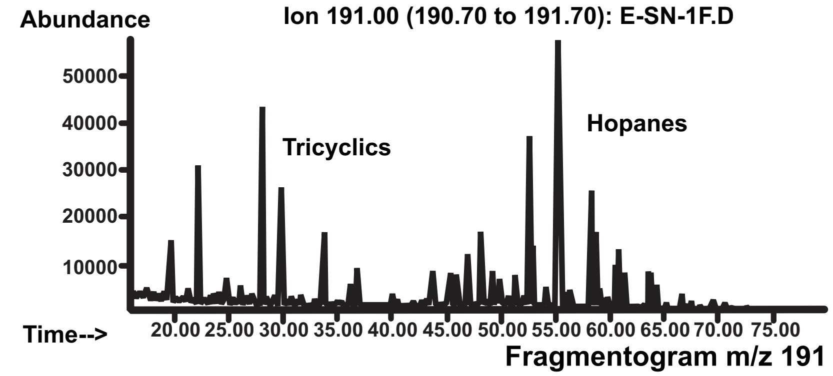
The steranes ternary diagram (above) shows that C27 steranes predominate over C29 steranes in the oil samples , indicating higher presence of marine organic matter than terrestrial organic matter in the source rocks.

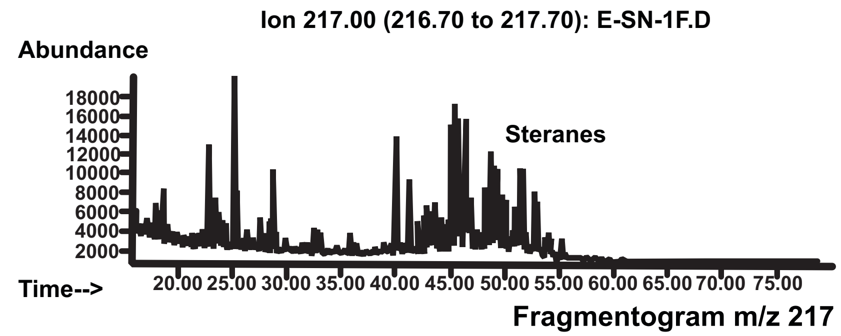
- In summary the oils in the basin correlate with generating facies deposited during the Cretaceous in siliciclastic marine shelf environments, with variable terrestrial organic matter input. The Cretaceous sedimentary sequence in the Upper Magdalena Valley includes units like the Villeta and Olini groups that could match the generating facies indicated by the crude oils in the basin.

Chromatography

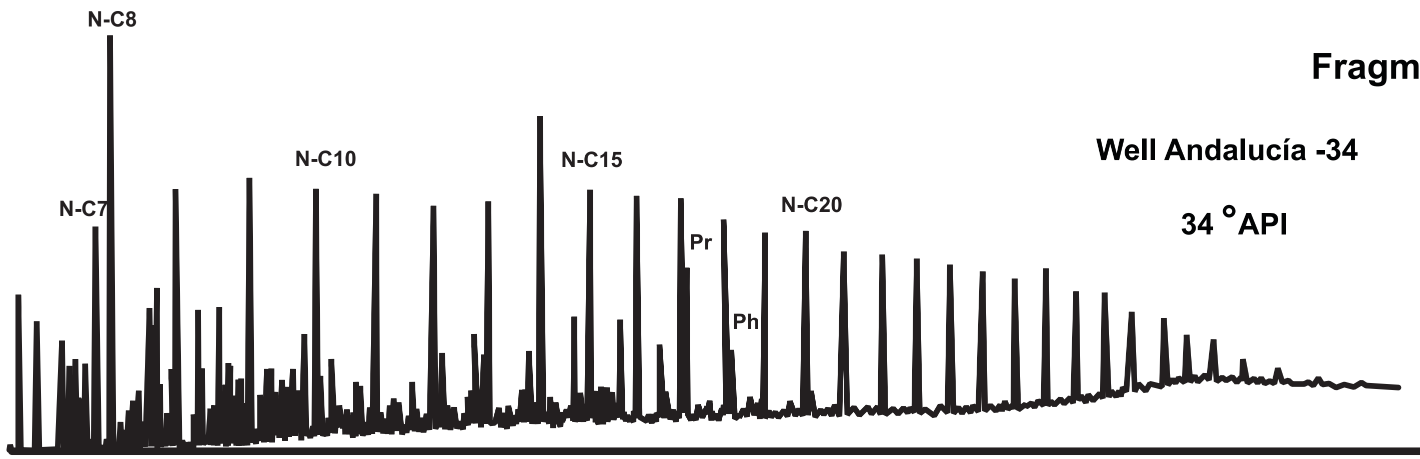
The Upper Magdalena crude oils are characterized by the presence of low molecular weight paraffins and Pristane/Phytane ratio > 1.0.

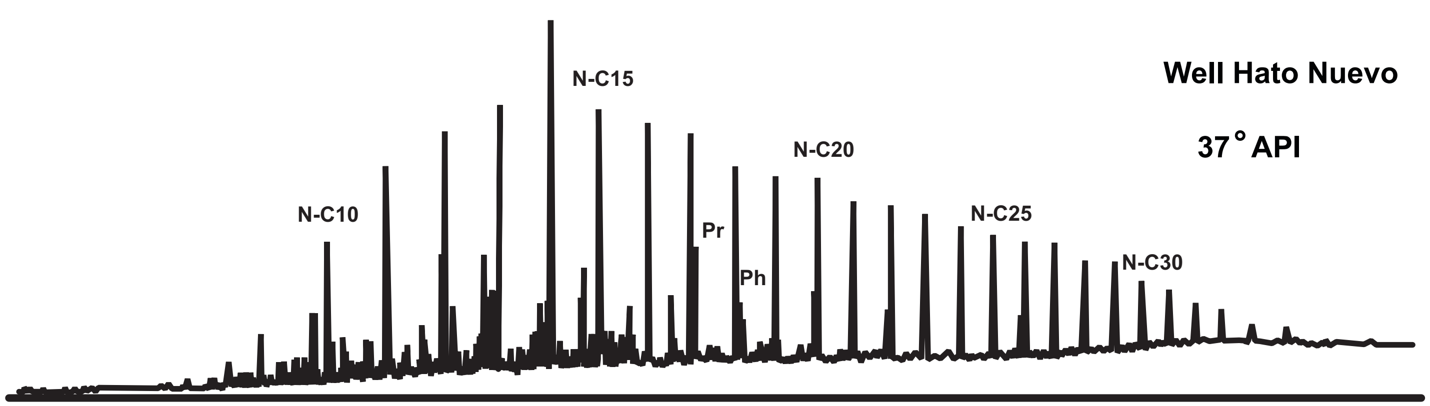
Some crude oils, like the Hato Nuevo well, although having high API gravity, shows low levels of biodegradation eliminating the low molecular weight paraffins.





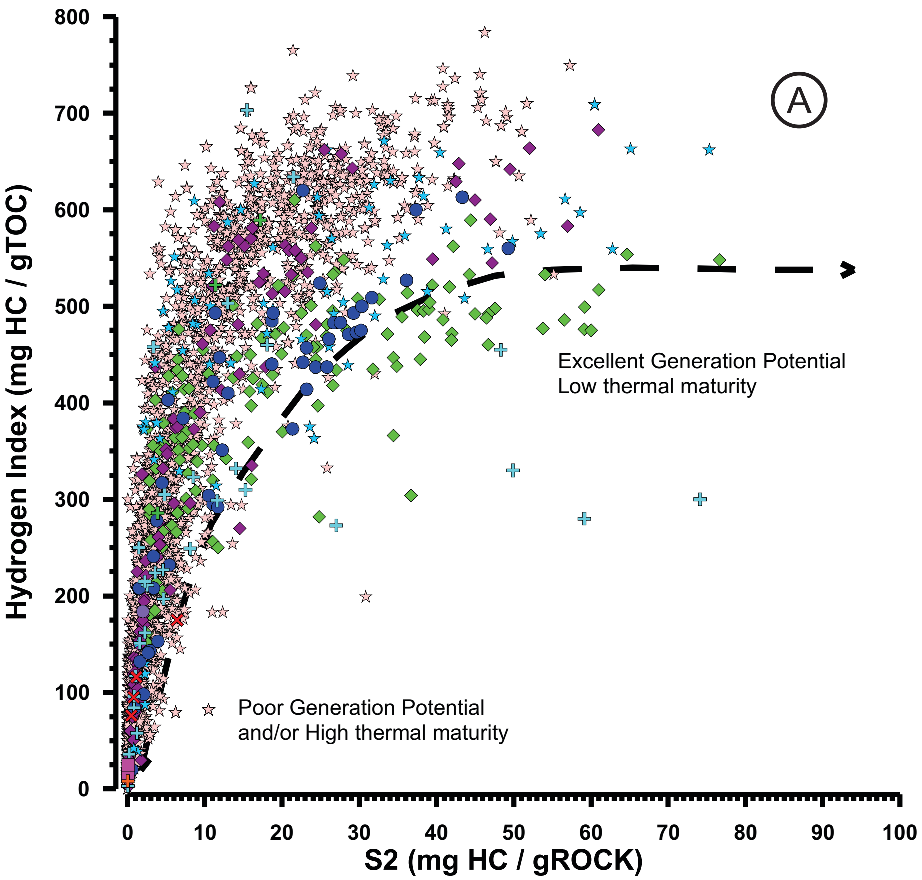
Fragmentograms

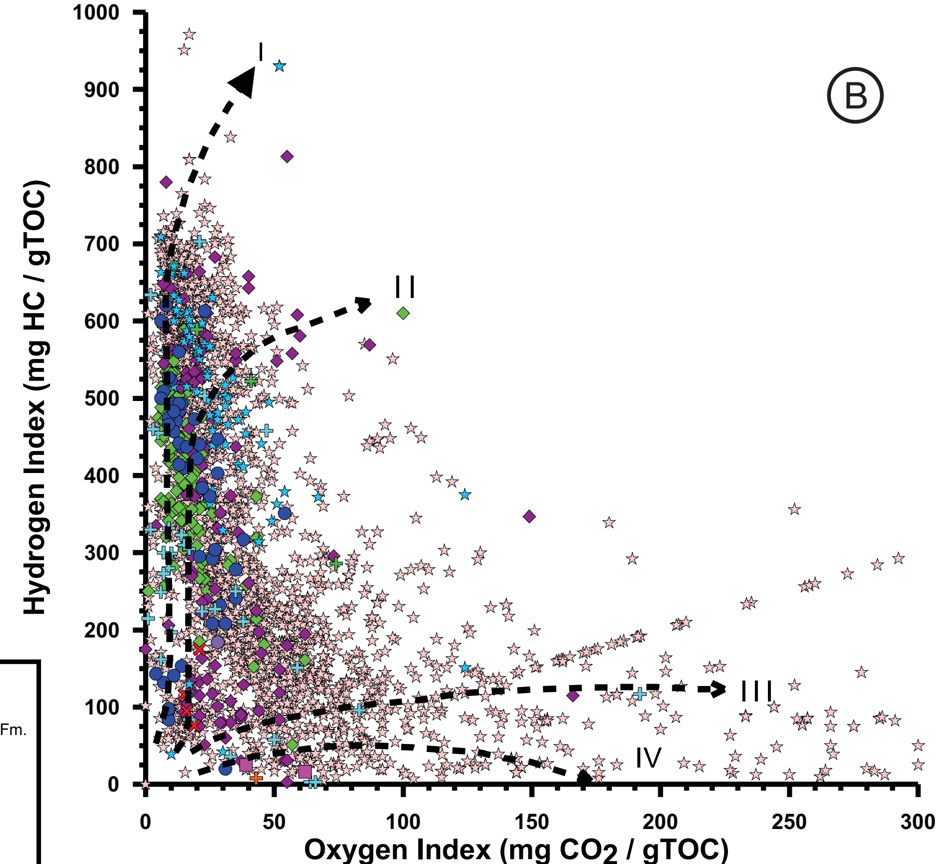


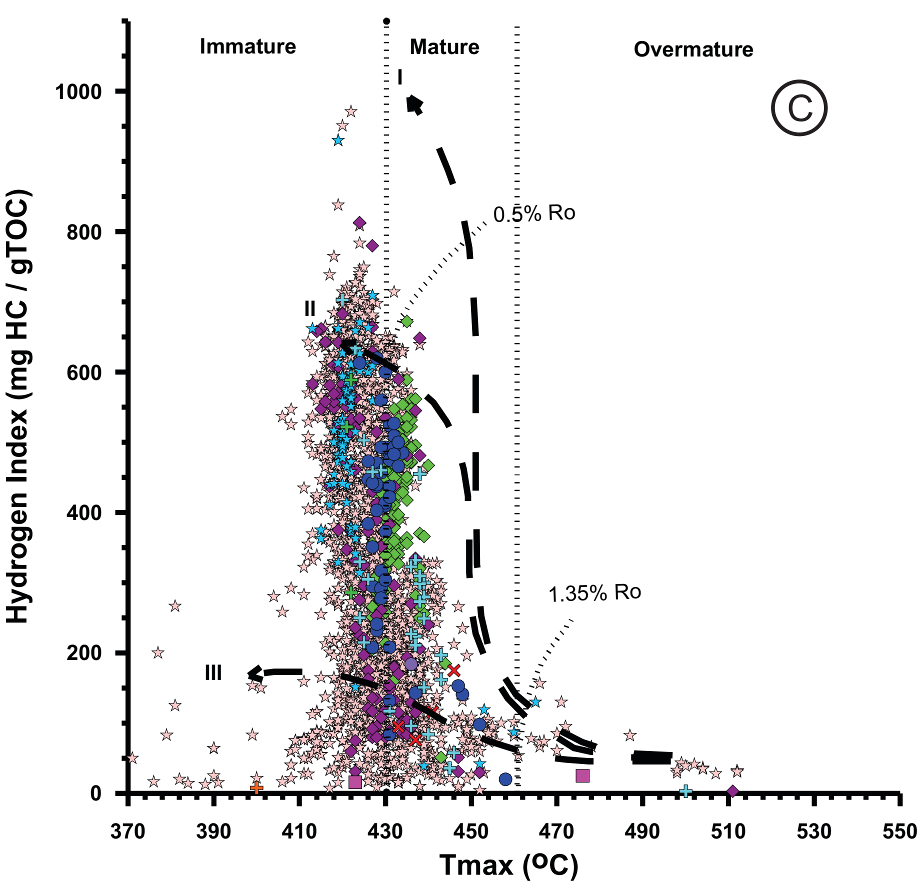


Chromatograms

Source Rock Characterization





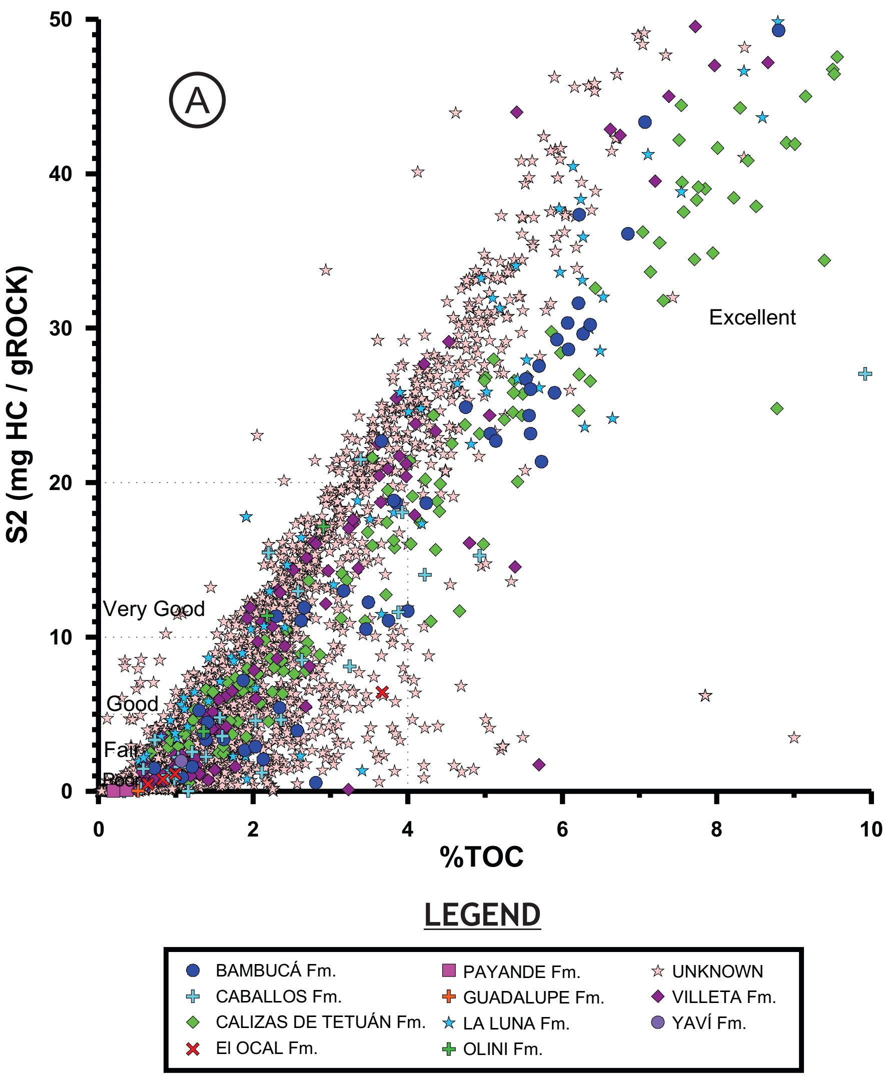


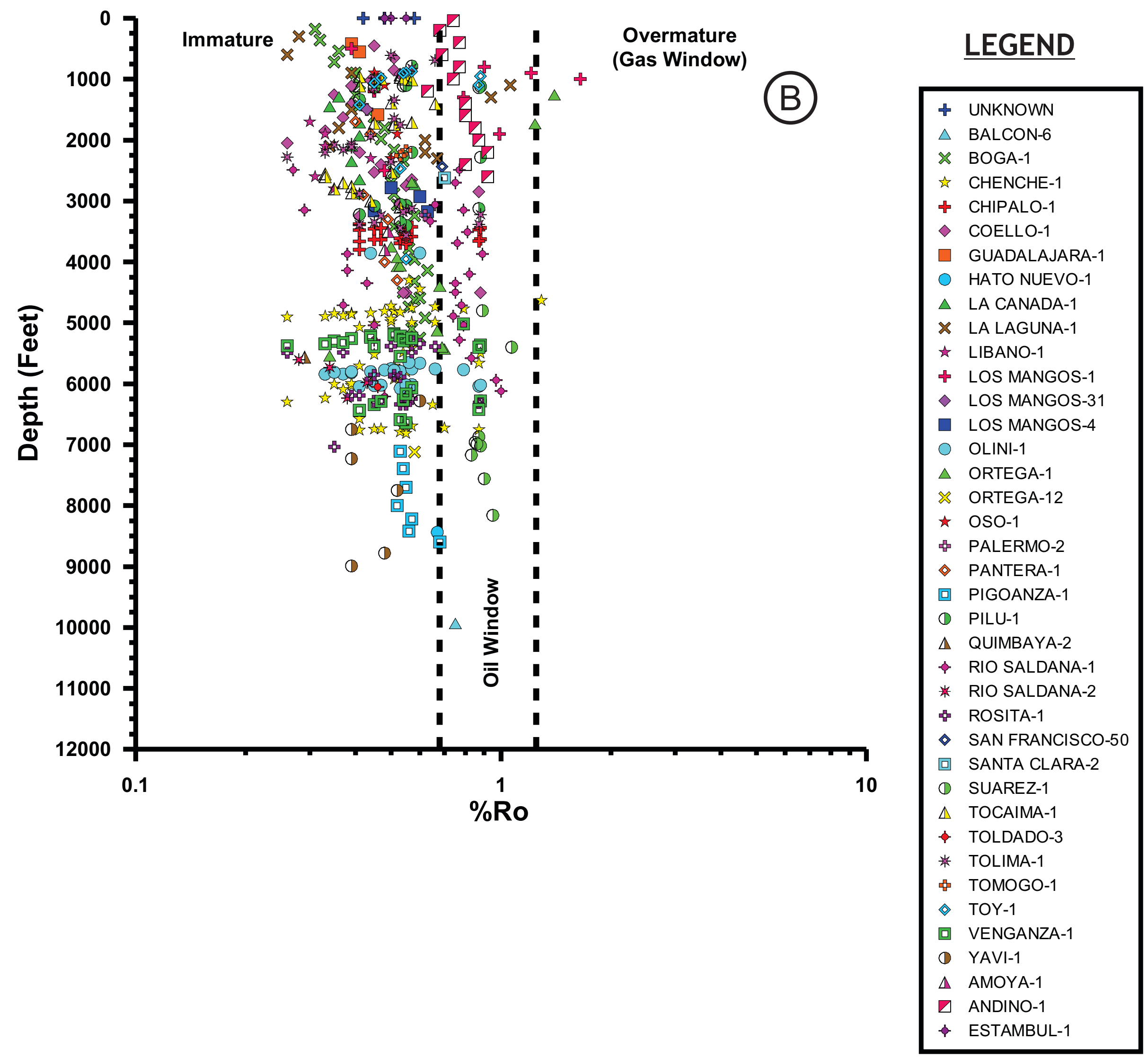
- The data obtained from pyrolysis Rock-Eval of rock samples for Hydrogen Index (HI) and S2 peak, indicate that samples from the Cretaceous Caballos, Calizas de Tetuán, Bambucá, La Luna and Villeta formations have good to excellent generation potential (HI > 200mg HC/g TOC and S2 > 5 mg HC/g rock) (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples from the Cretaceous Caballos, Calizas de Tetuán, Bambucá, La Luna and Villeta formations have type I - II oil-prone kerogen. Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that many samples from the Cretaceous units mentioned, have reached early maturity to oil generation peak conditions in the basin (Figure C).

Source Rock Characterization





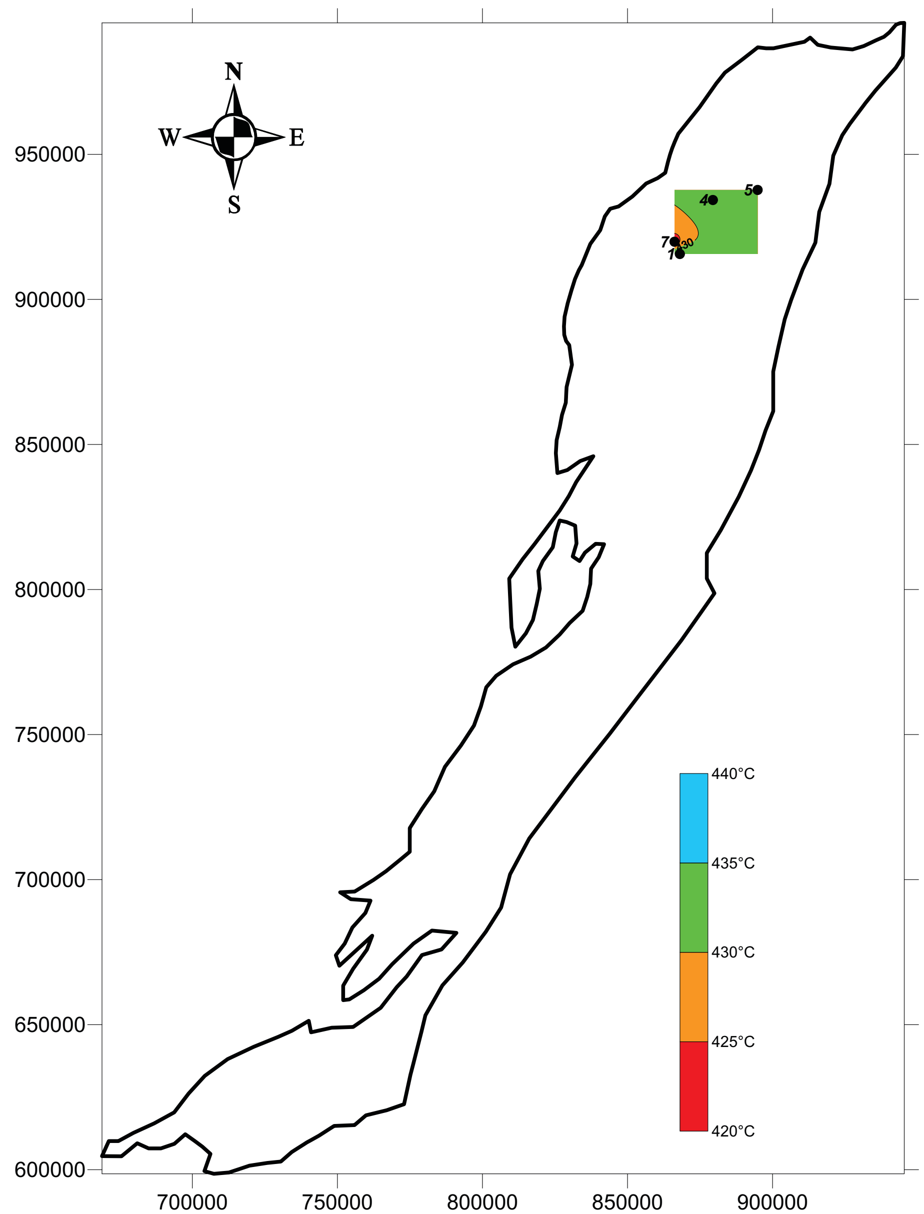
- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that there are samples from Cretaceous units (Caballos, Calizas de Tetuán, Bambucá, La Luna and Villeta formations), with good to excellent oil generation potential (S2 up to 50 mg HC/g rock and % TOC up to 10) (Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence ranges from immature to oil generation peak (Figure B).

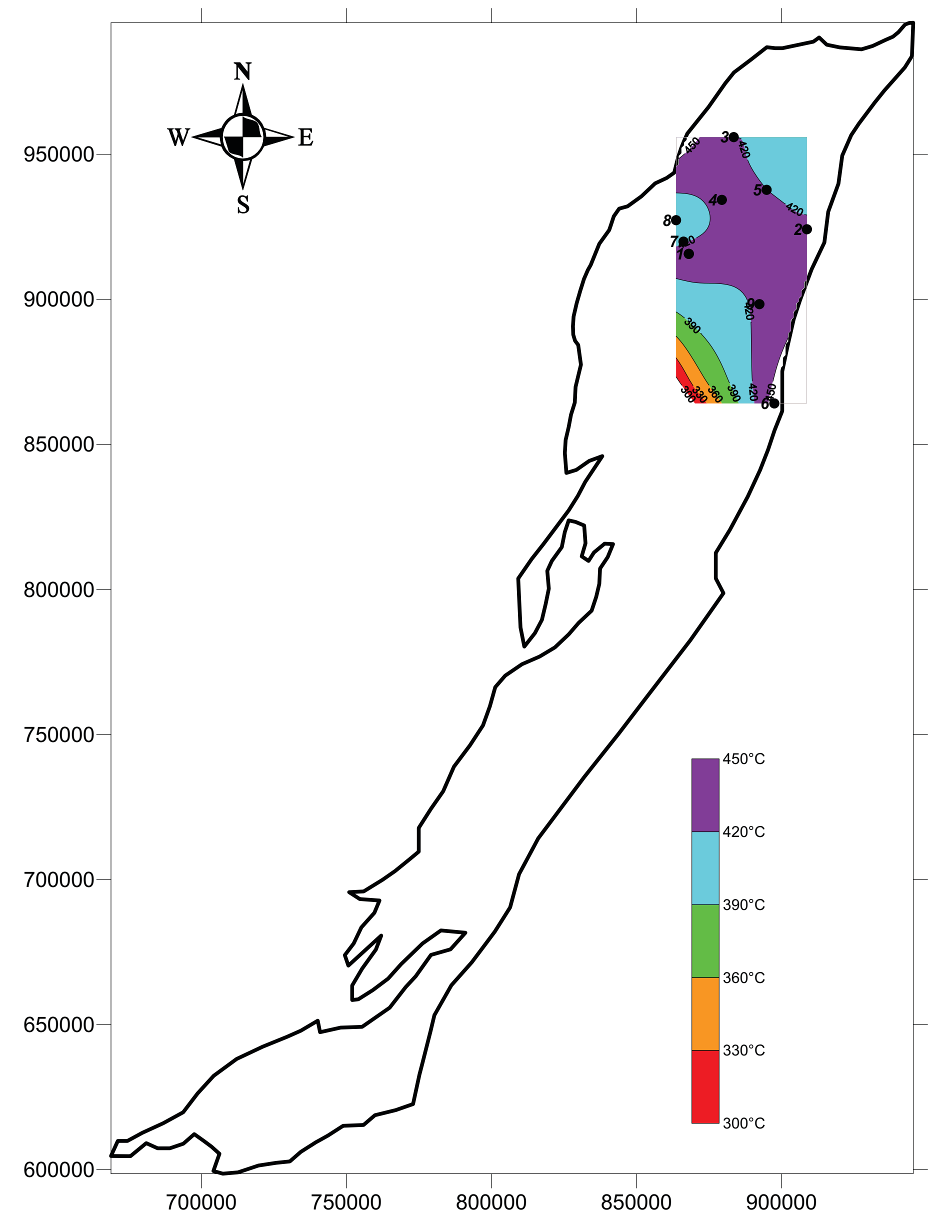
-In summary, the best source rocks at the basin, with good to excellent oil generation potential intervals are the Cretaceous rocks of the Caballos, Calizas de Tetuán, Bambucá, La Luna and Villeta formations. Tmax and %Ro maturity data indicate that the Cretaceous oil-prone formations are mature for hydrocarbons generation in the basin.

Source Rock Quality and Maturity Maps

Maximum Temperature (Tmax)



Tetuán Fm.



La Luna Fm.

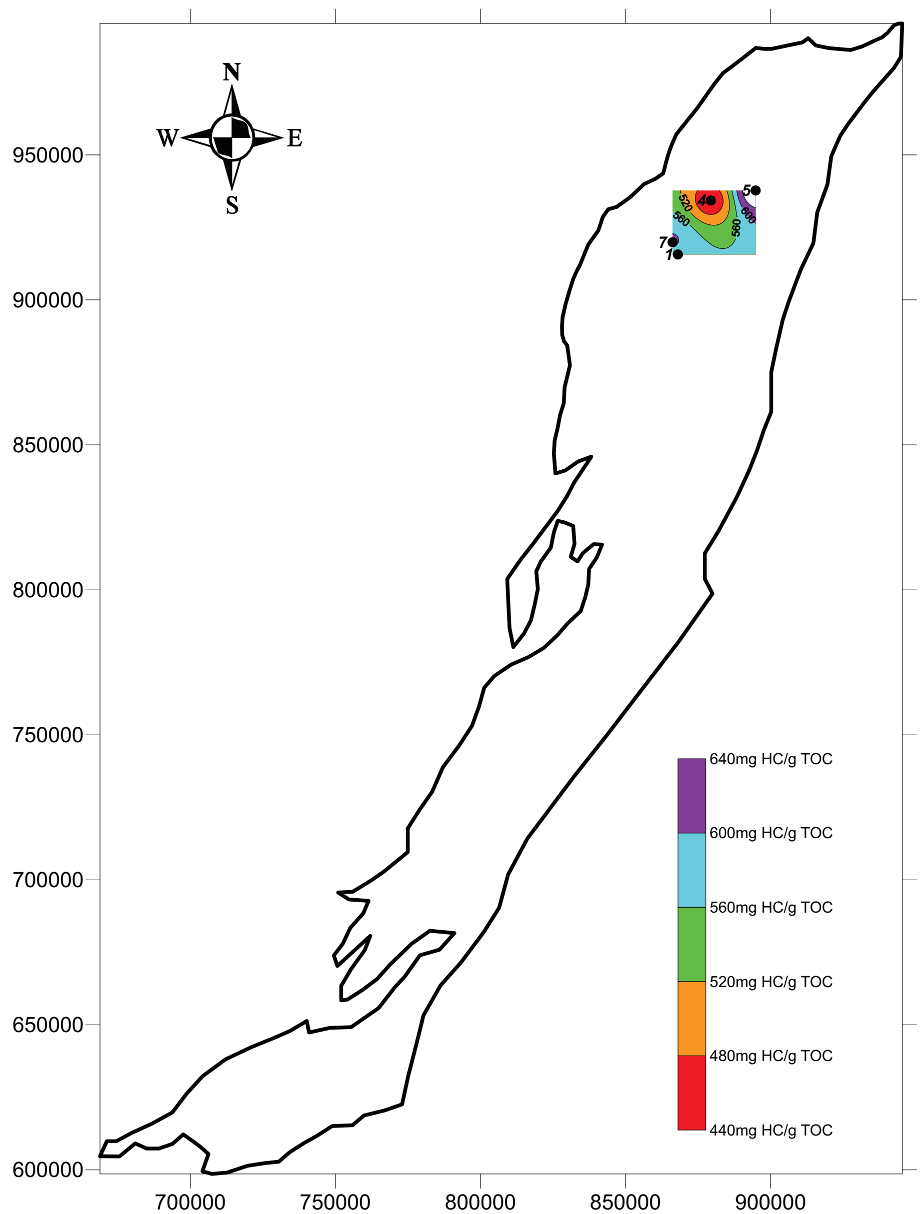
LEGEND

1. BOGA-1
2. CHENCHE-1
3. MICHÚ-1
4. PACANDE-1
5. ROSITA-1
6. STRATIGRAPHIC-1
7. TOLDADO-1
8. TOY-1
9. YAVÍ-1

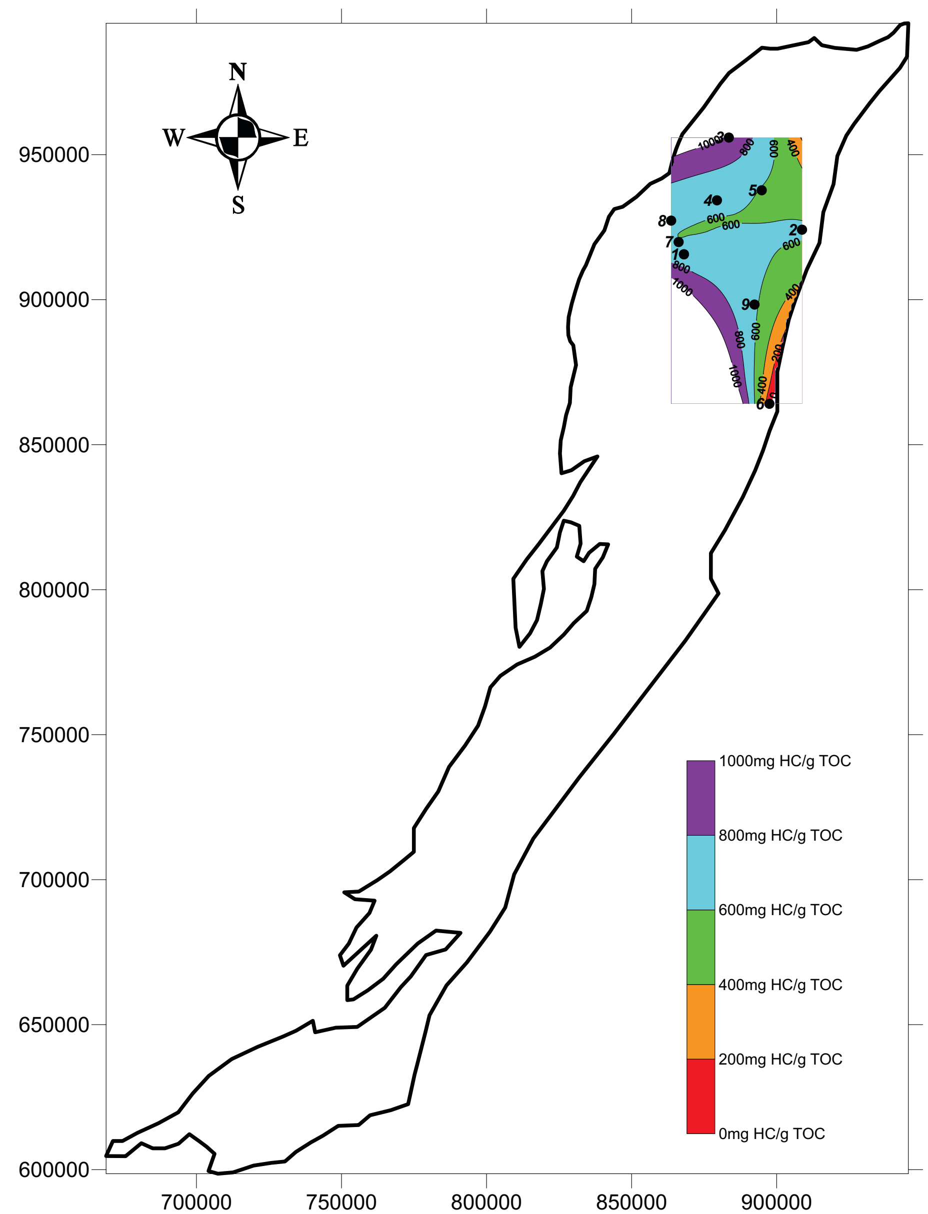
Map datum: Magna Sirgas
Coord. origin: Bogotá

Source Rock Quality and Maturity Maps

Hydrogen Index



Tetuán Fm.



La Luna Fm.

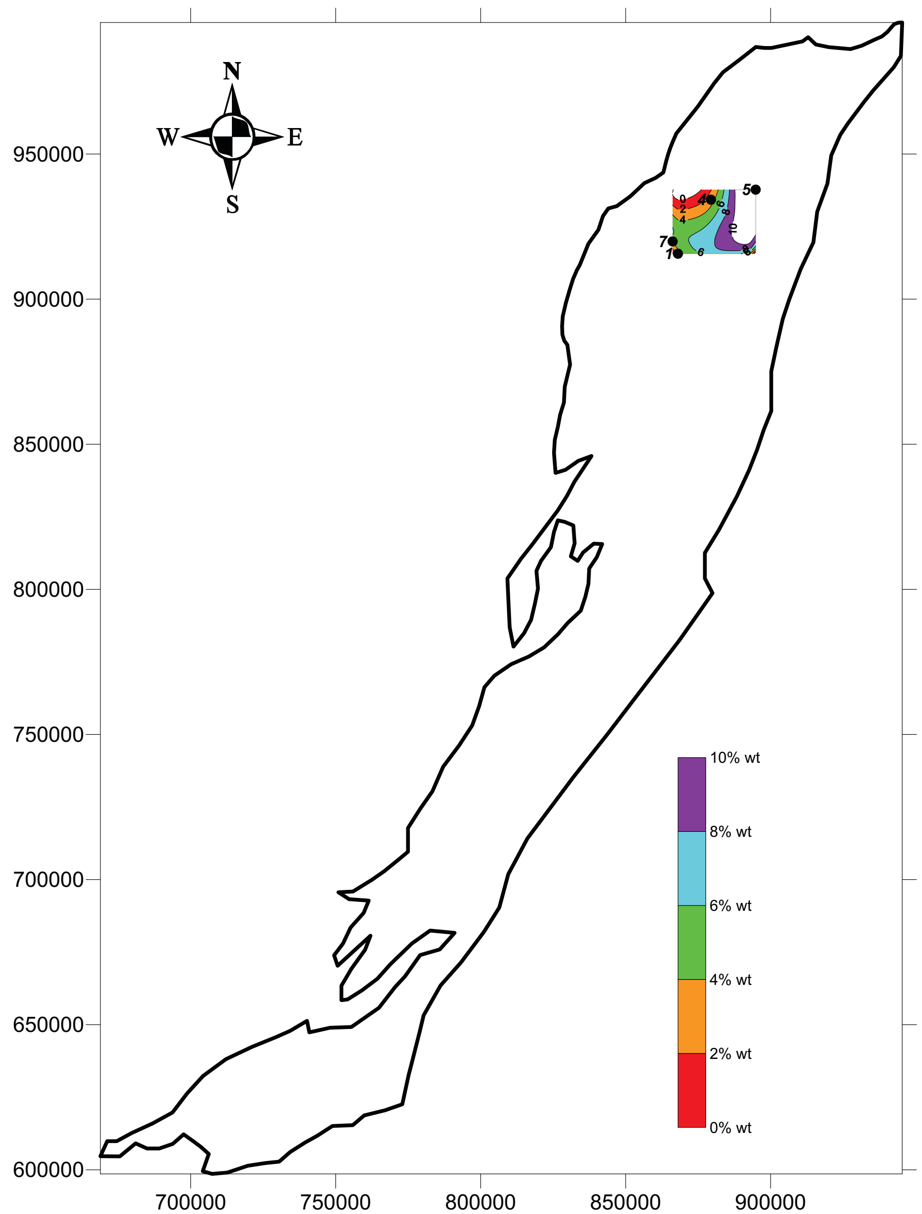
LEGEND

1. BOGA-1
2. CHENCHE-1
3. MICHÚ-1
4. PACANDE-1
5. ROSITA-1
6. STRATIGRAPHIC-1
7. TOLDADO-1
8. TOY-1
9. YAVÍ-1

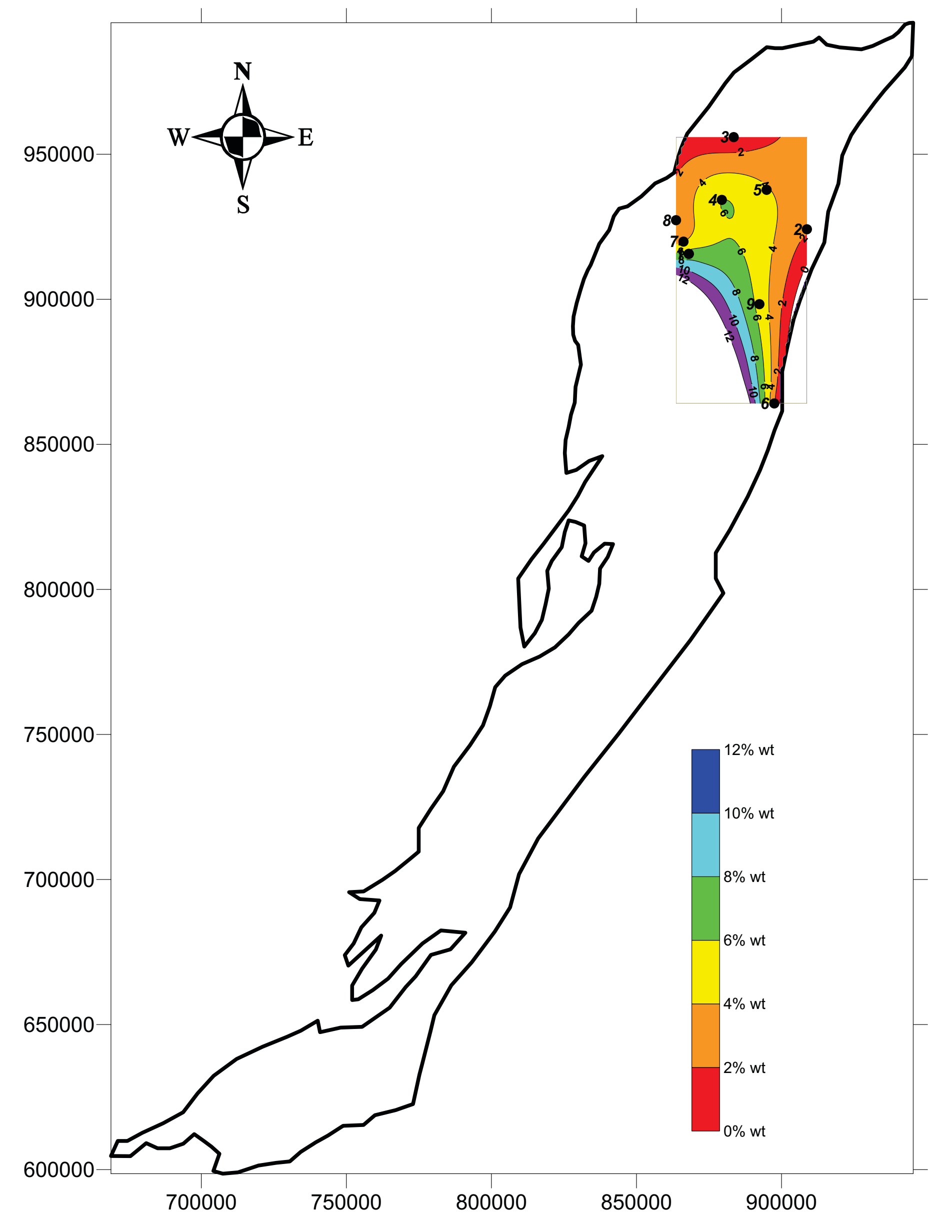
Map datum: Magna Sirgas
Coord. origin: Bogotá

Source Rock Quality and Maturity Maps

Organic Matter Content (TOC)



Tetuán Fm.



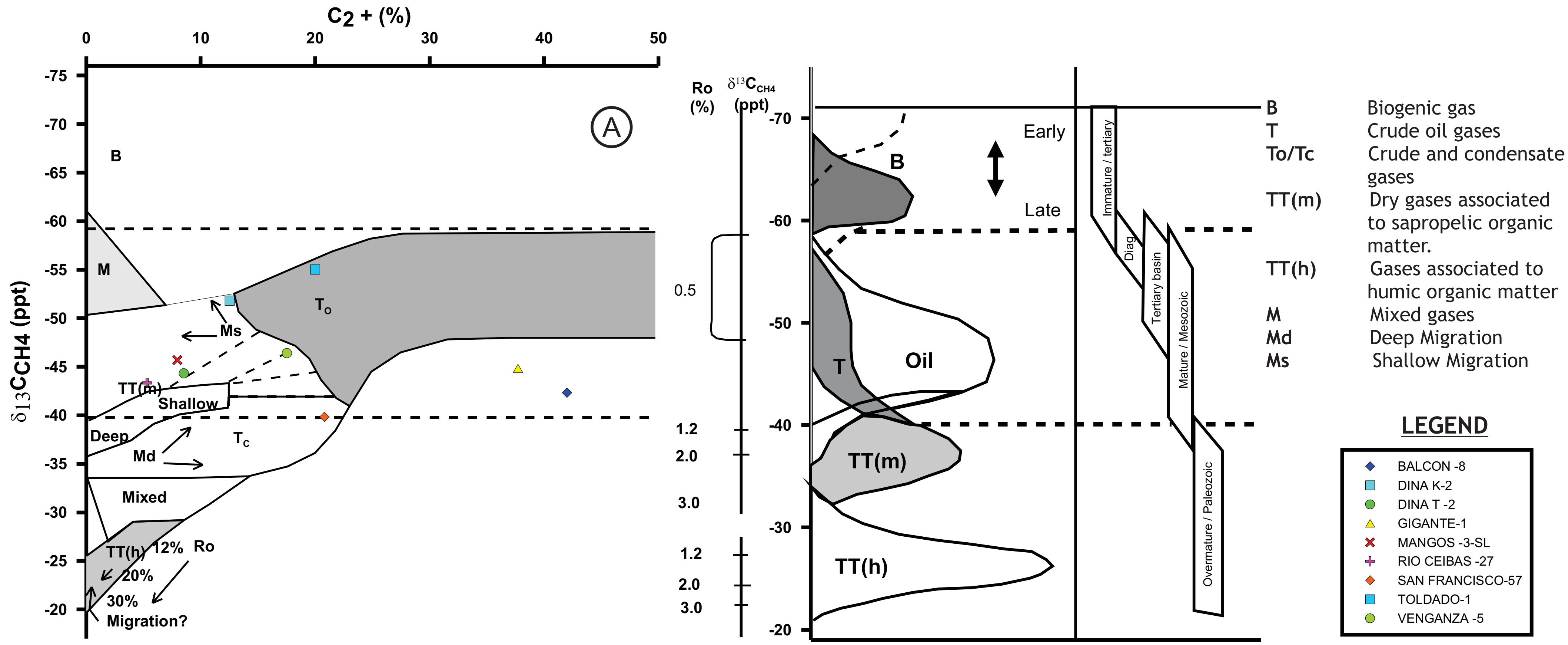
La Luna Fm.

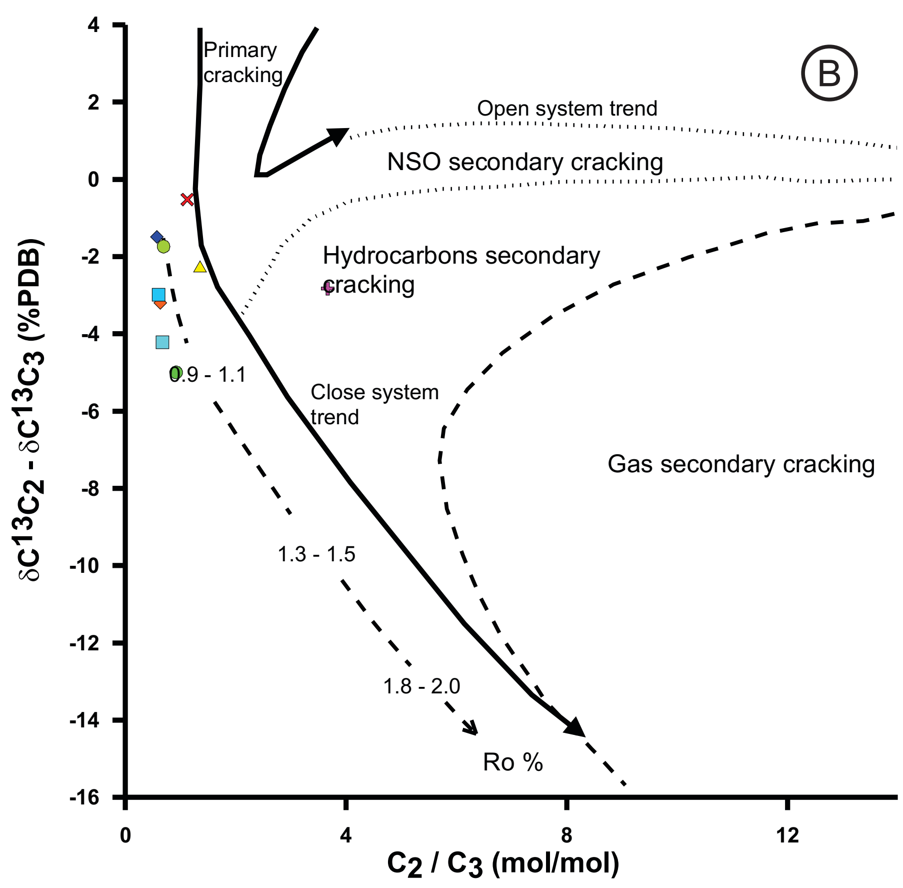
LEGEND

1. BOGA-1
2. CHENCHE-1
3. MICHÚ-1
4. PACANDE-1
5. ROSITA-1
6. STRATIGRAPHIC-1
7. TOLDADO-1
8. TOY-1
9. YAVÍ-1

Map datum: Magna Sirgas
Coord. origin: Bogotá

Gas Characterization



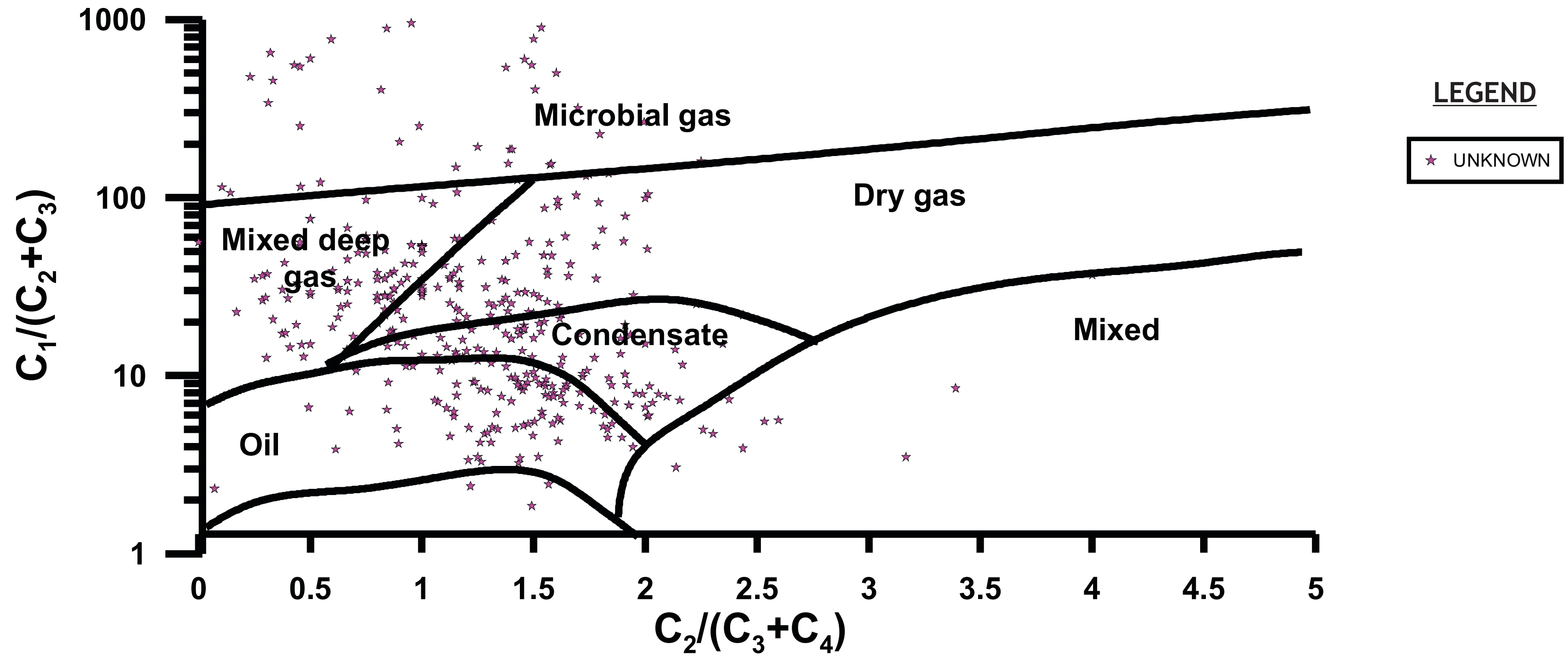


The samples taken in the Upper Magdalena Valley basin correspond to crude oil gases.

- The C2+(%) vs d13C Ch4 (ppm) diagram (Schoell, 1983), suggests that the gas samples are thermogenic in origin with predominance of mixtures (Figure A).

- The C2/C3 vs d13C C2 - d13C C3 diagram, suggest that the gas samples analized were originated by primary cracking (Figure B).

Surface Geochemistry

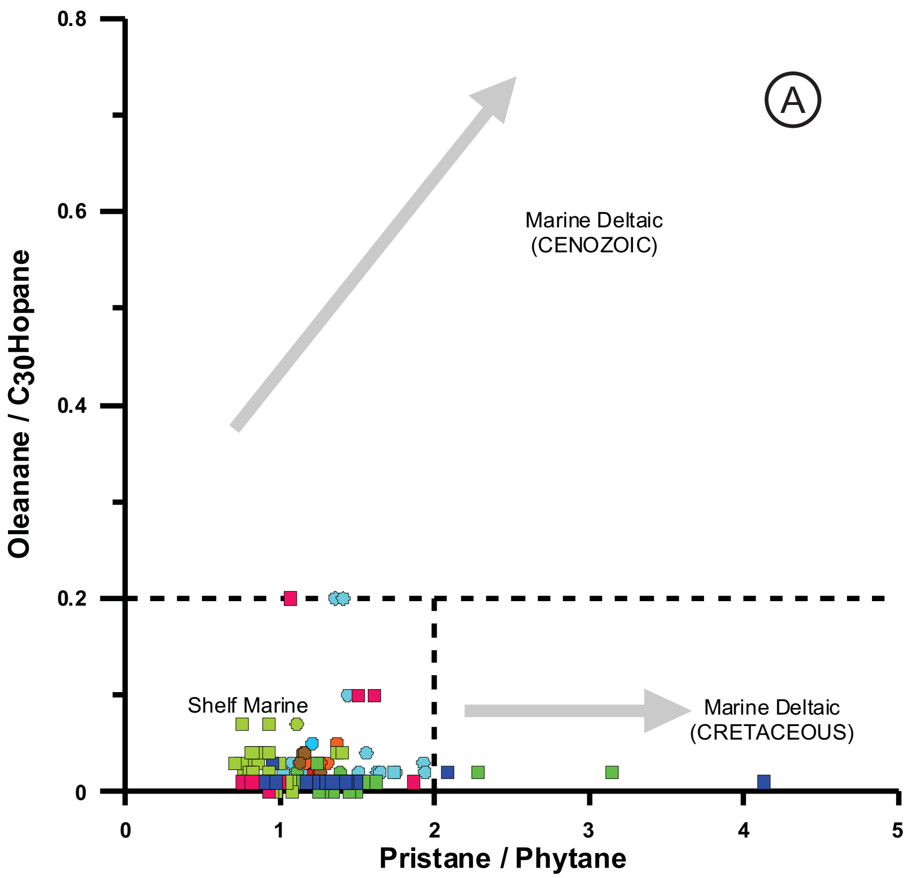


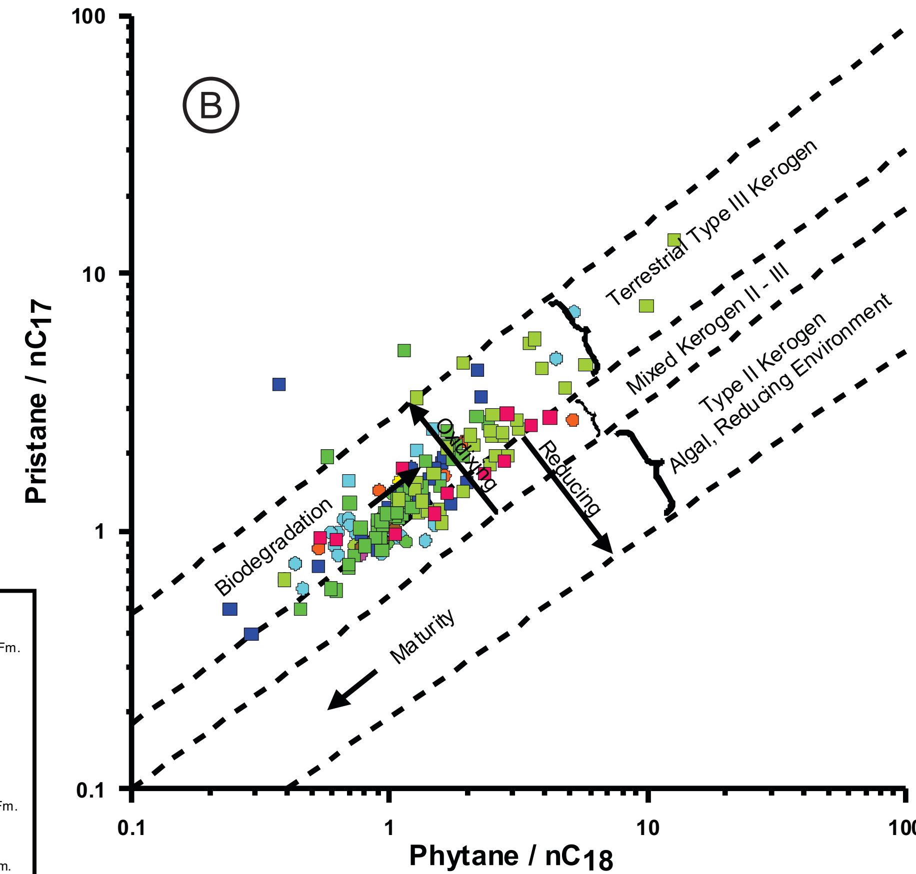
Compositional data from surface geochemistry samples indicate that the hydrocarbons are thermogenic, formed mainly during late oil and gas generation window (condensates) with minor presence of early oil hydrocarbons (gas generation window).

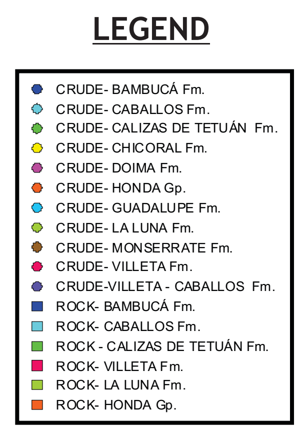
Mixing between different thermal maturity hydrocarbons is also indicated by the data.

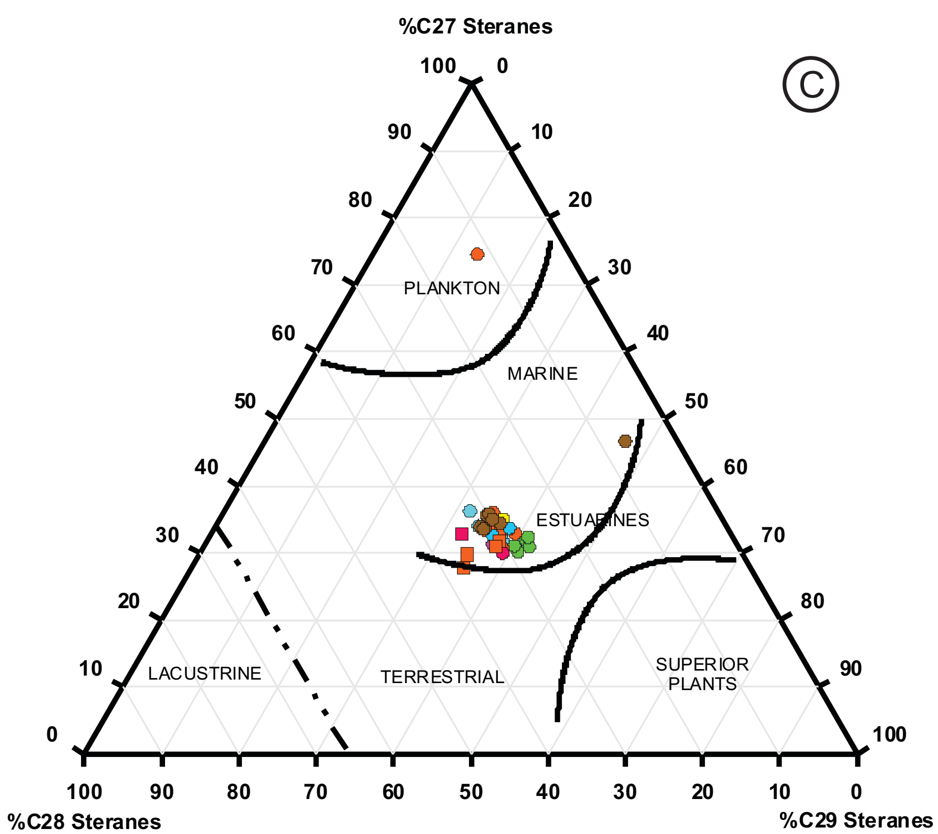
There are very few samples of microbial gas to consider biogenic gas an important process in the basin.

Petroleum Systems (Crude-Rock Correlations)







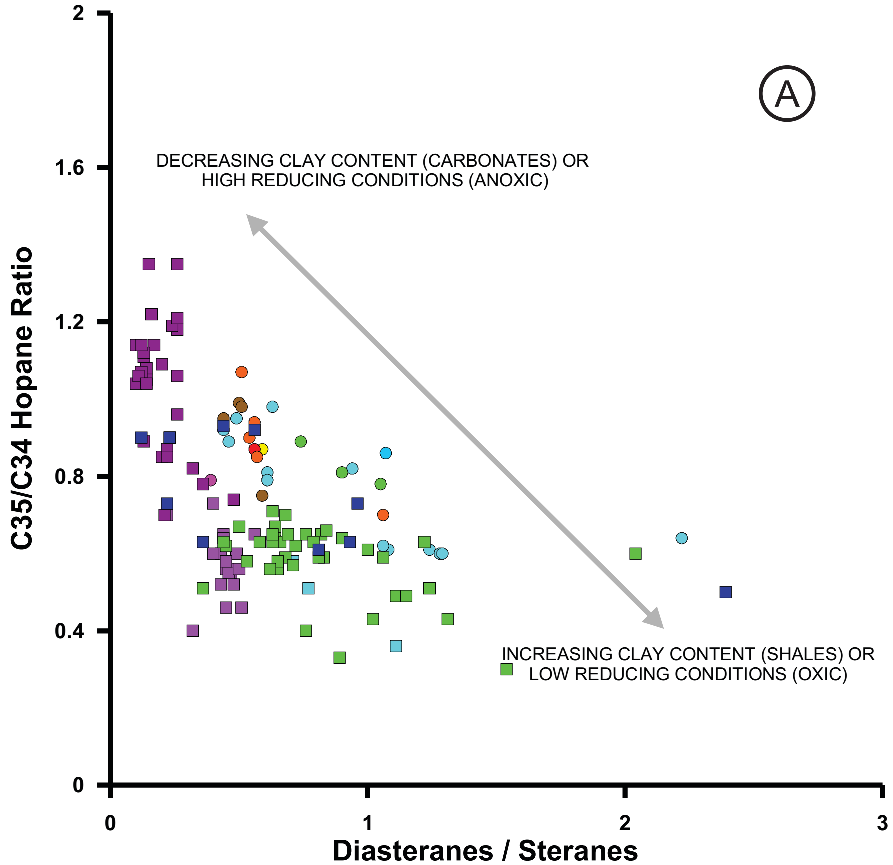


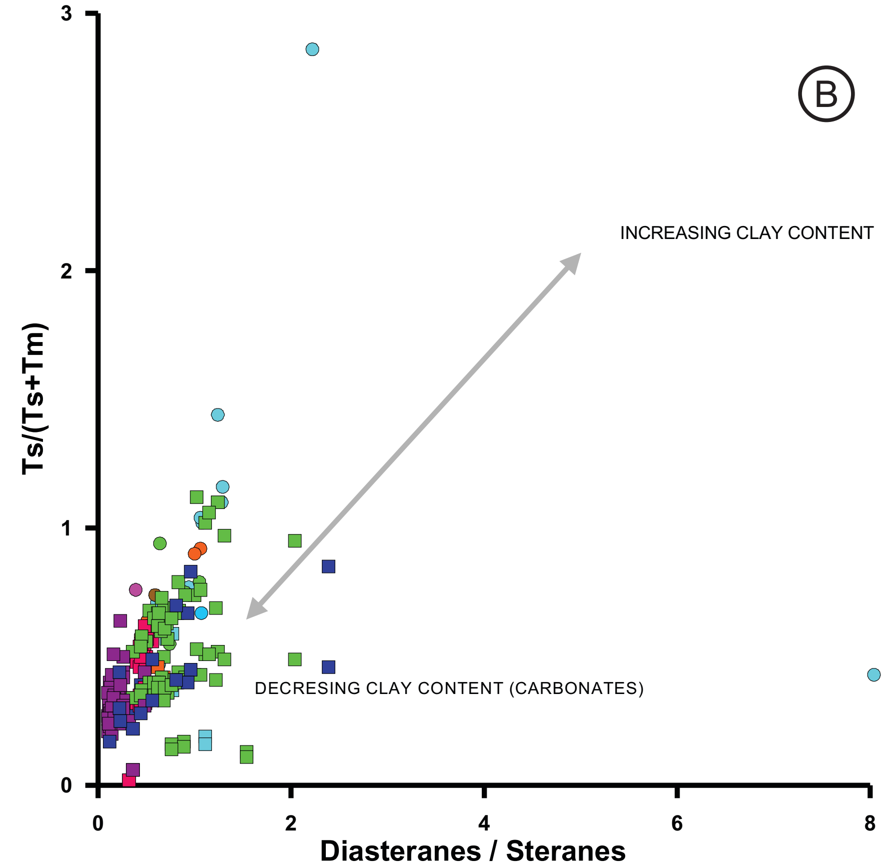
- The Pristane/Phytane vs Oleanane/C30 Hopane (Oleanane Index) graph shows that oils from the Caballos, Monserrate-Guadalupe, Calizas de Tetuán and Honda reservoirs have low oleanane index values (<0.2) and Pr/Ph values (<2), and correlate well with rock extracts from the Caballos, Bambuca, Calizas de Tetuán, La Luna and Villeta formations, suggesting that these units are the sources for the hydrocarbons found in those reservoirs at the basin. Additionally the low oleanane values correlate well with the Cretaceous age of the sources (Figure A).

- The Phytane/nC18 vs Pristane/nC17 graph shows good correlation between the crude oils found in the reservoirs mentioned above with rock extracts from samples of the Caballos, Bambuca, Calizas de Tetuán, La Luna and Villeta formations. Indicating that the oils have origin from terrestrial organic matter and to a minor extent from mixed kerogen (type II-III), but additionally that the crudes and rocks have similar thermal maturities (Figure B).

- The steranes ternary plot shows less correlation between crude oils and rock extracts, because there are very few data from extracts in the basin, mainly from the Cenozoic Honda Group, which is not considered a good and active source rock in the basin (Figure C). The data suggests these oils were generated from rocks deposited in an estuarine to marine environment

Petroleum Systems (Crude-Rock Correlations)





LEGEND

- CRUDE- CABALLOS Fm.
- CRUDE- CALIZAS DE TETUÁN Fm.
- CRUDE- CHICORAL Fm.
- CRUDE- DOIMA Fm.
- CRUDE- HONDA Gr.
- CRUDE- GUADALUPE Fm.
- CRUDE- MONSERRATE Fm.
- ROCK- BAMBUCÁ Fm.
- ROCK- CABALLOS Fm.
- ROCK- CALIZAS DE TETUÁN Fm.
- ROCK- HONDA Gr.
- ROCK- LA LUNA Fm.
- ROCK- VILLETA Fm.

- The Homohopanes Index (C35/C34 Hopane ratio) vs diasteranes/steranes graph shows some correlation between the crude oils from the Caballos, Monserrate-Guadalupe, Calizas de Tetuán and Honda reservoirs with rock extracts from the Calizas de Tetuán, La Luna and Villeta formations, indicating also that these crudes were formed from rocks deposited in suboxic environments with variable clay content (Figure A).

- The Ts/(Ts+Tm) vs diasteranes/steranes graph shows good correlation between crude oils from the reservoirs mentioned with rock extracts from the Calizas de Tetuán, La Luna and Villeta formations. Additionally this graph suggests that oils were formed from clay-poor rocks.

Crude - Rock correlations from samples at the basin suggest the following:

- Good correlation between crudes from the Caballos, Guadalupe/Monserrate, Doima, Chicoral and Honda reservoirs and extracts from the Villeta and Caballos formations (low diasteranes/steranes, low Ts/Tm, C35/C34 hopane ratio < 1, low oleanane index, Pristane/Phytane < 2, and predominance of C27/C29 steranes).

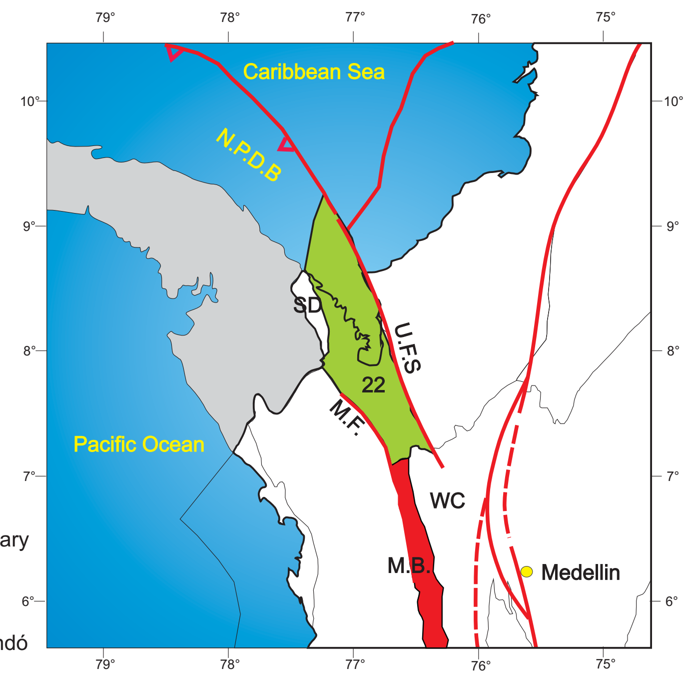
- This indicates the presence of several active petroleum systems at the basin named as follows: Caballos (!), Villeta Group - Caballos (!), Villeta Group - Monserrate/Guadalupe (!), Villeta Group - Doima (.),Villeta Group - Chicoral (.), and Villeta Group - Honda (!).

URABÁ BASIN

Generalities
Wells and Seeps
Source Rock Characterization

Generalities

URABÁ BASIN
LOCATION AND BOUNDARIES



N.P.D.B. North Panama Deformed Belt

BOUNDARIES

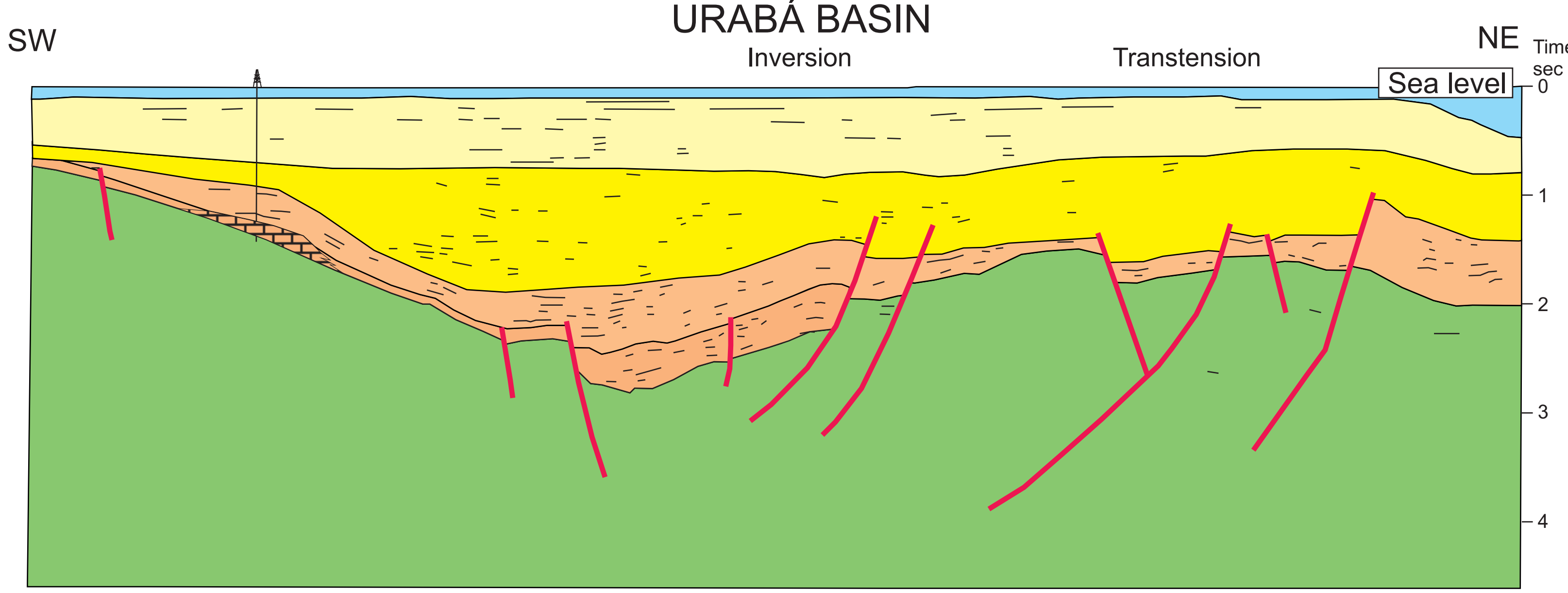
North-Northwest: Colombian-Panamá Boundary
East: Uramita fault system (U.F.S.)
South: Cretaceous rocks of the Western Cordillera (WC)
Southwest: Mandé batholith (M.B.) and Murindó fault
West: Serranía del Darien (SD)

From Barrero et al., 2007

The source rock geochemical information interpreted for the Urabá Basin includes %TOC and Rock-Eval Pyrolysis data from 3 samples taken in 1 location; additionally 3 organic petrography samples from 1 location were interpreted.

Due to the lack of crude oil geochemical data, crude oil interpretation was not made for the basin.

SCHEMATIC CROSS SECTION
URABÁ BASIN

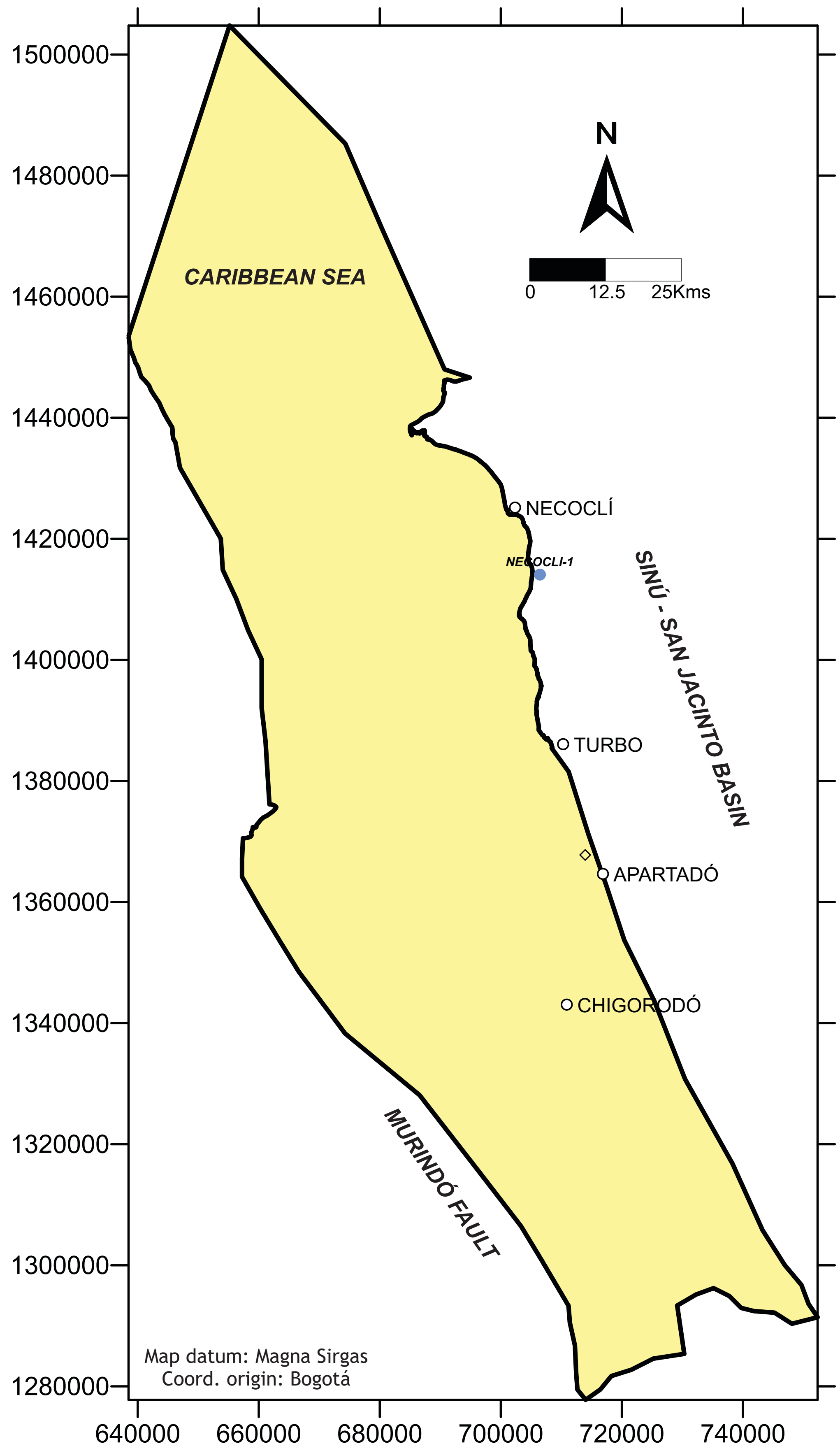


Color code according to the commission for the Geological Map of the World (2005)

Oceanic Crust | Paleogene | Neogene

From Barrero et al., 2007

Wells and Seeps

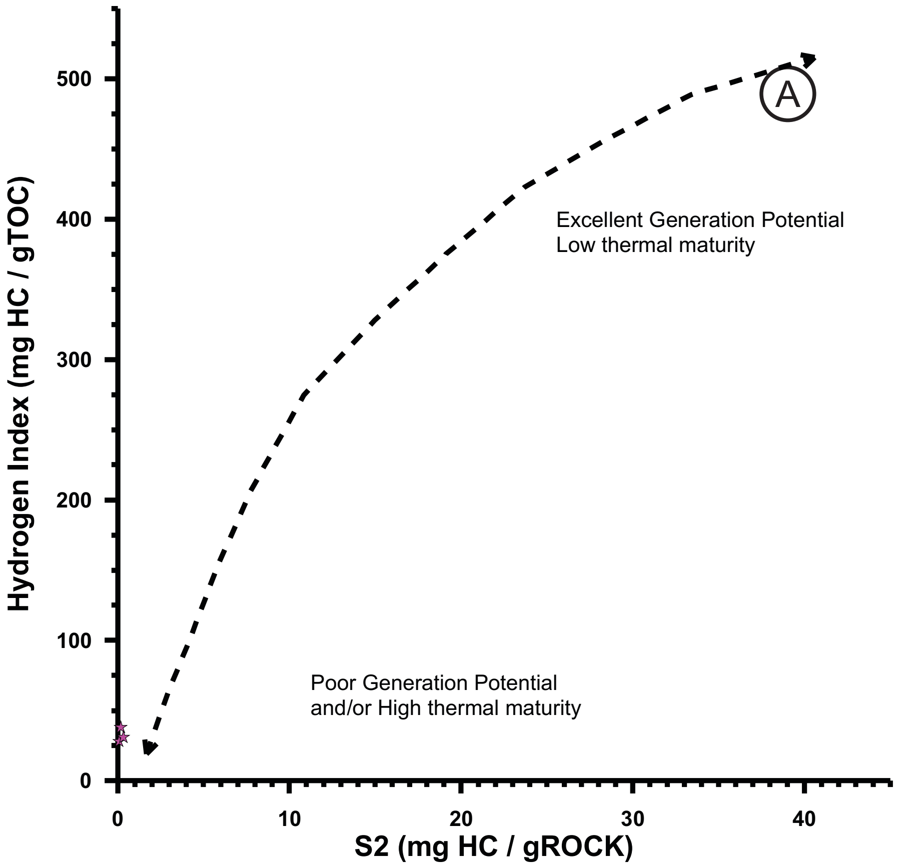


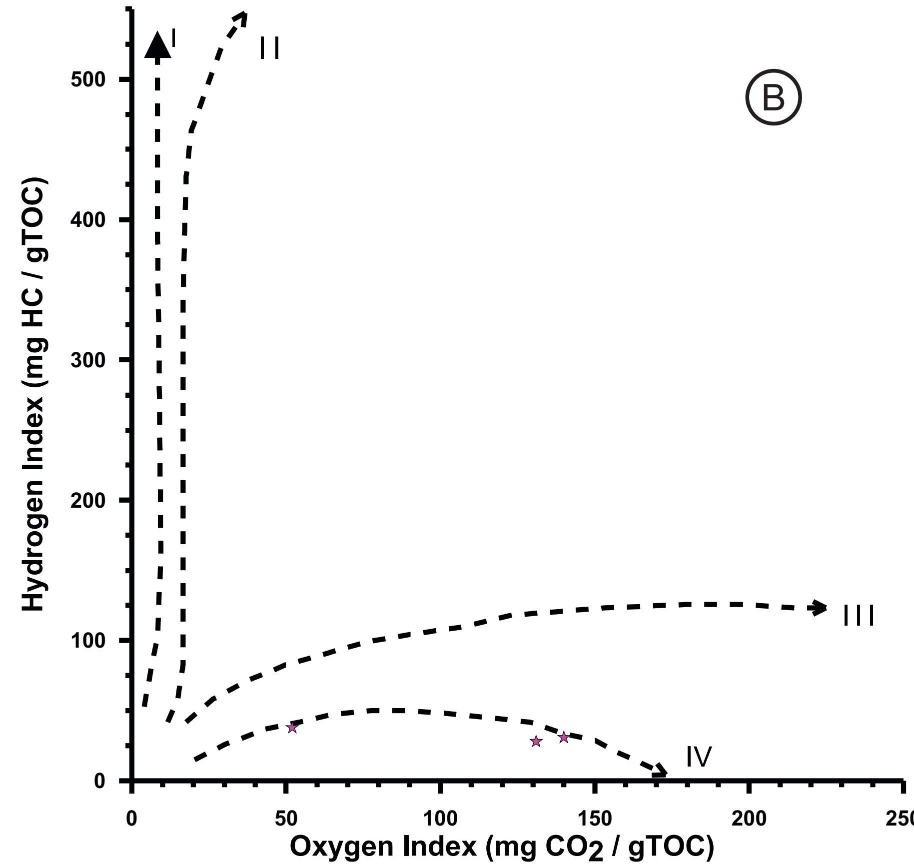
The number of wells and/or surface locations with geochemical information in the Urabá Basin is 1.

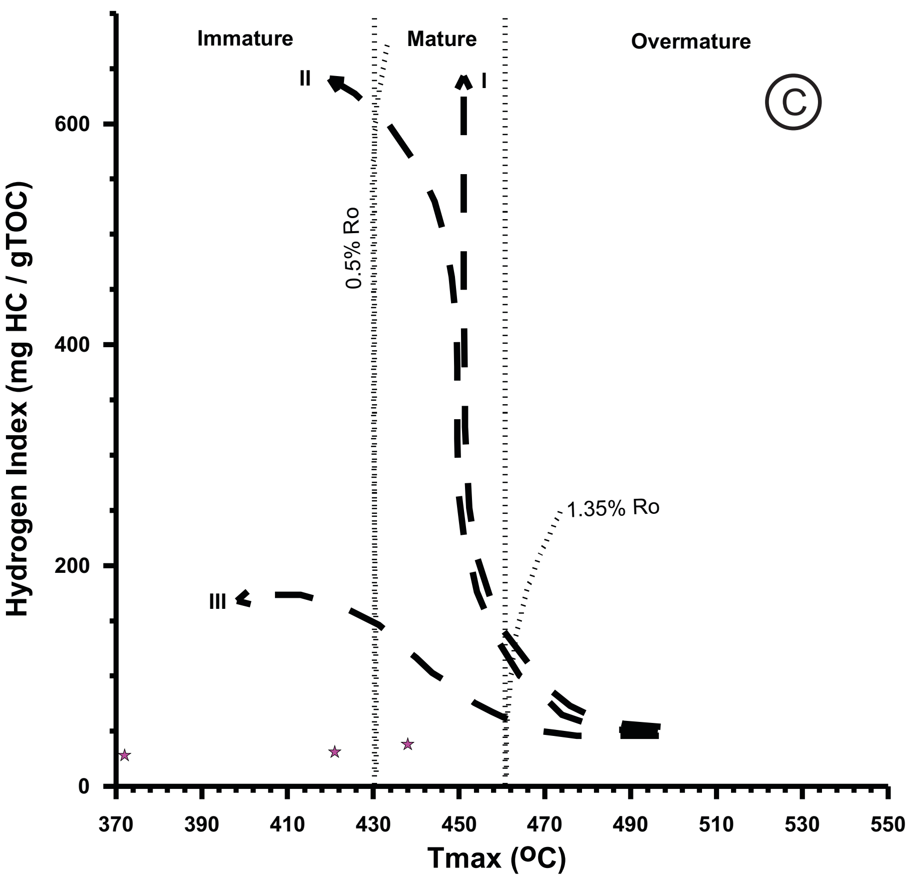
There is one seep reported in this basin.

- Wells with geochemical information
- Undetermined seeps
- Cities/Towns

Source Rock Characterization





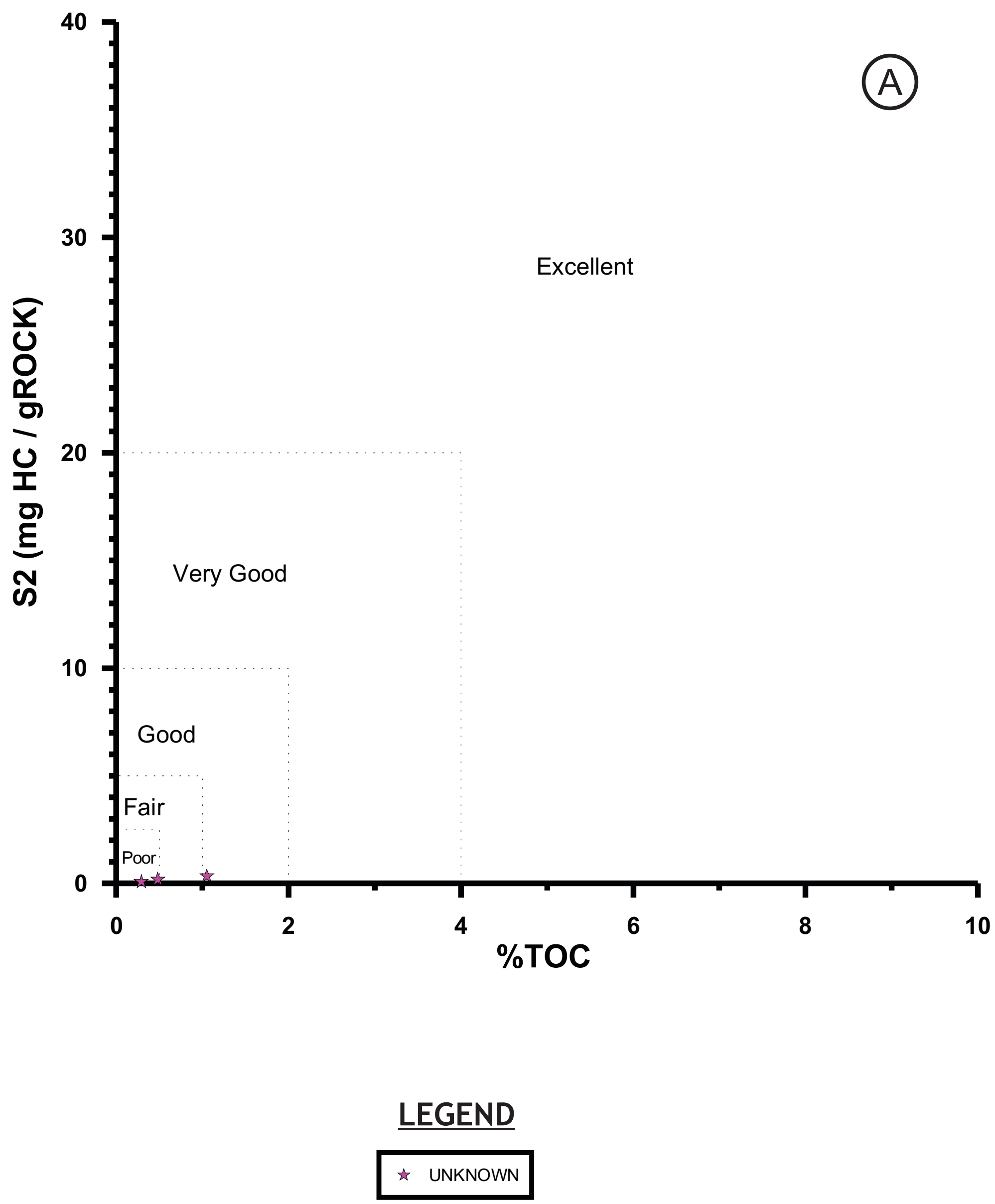


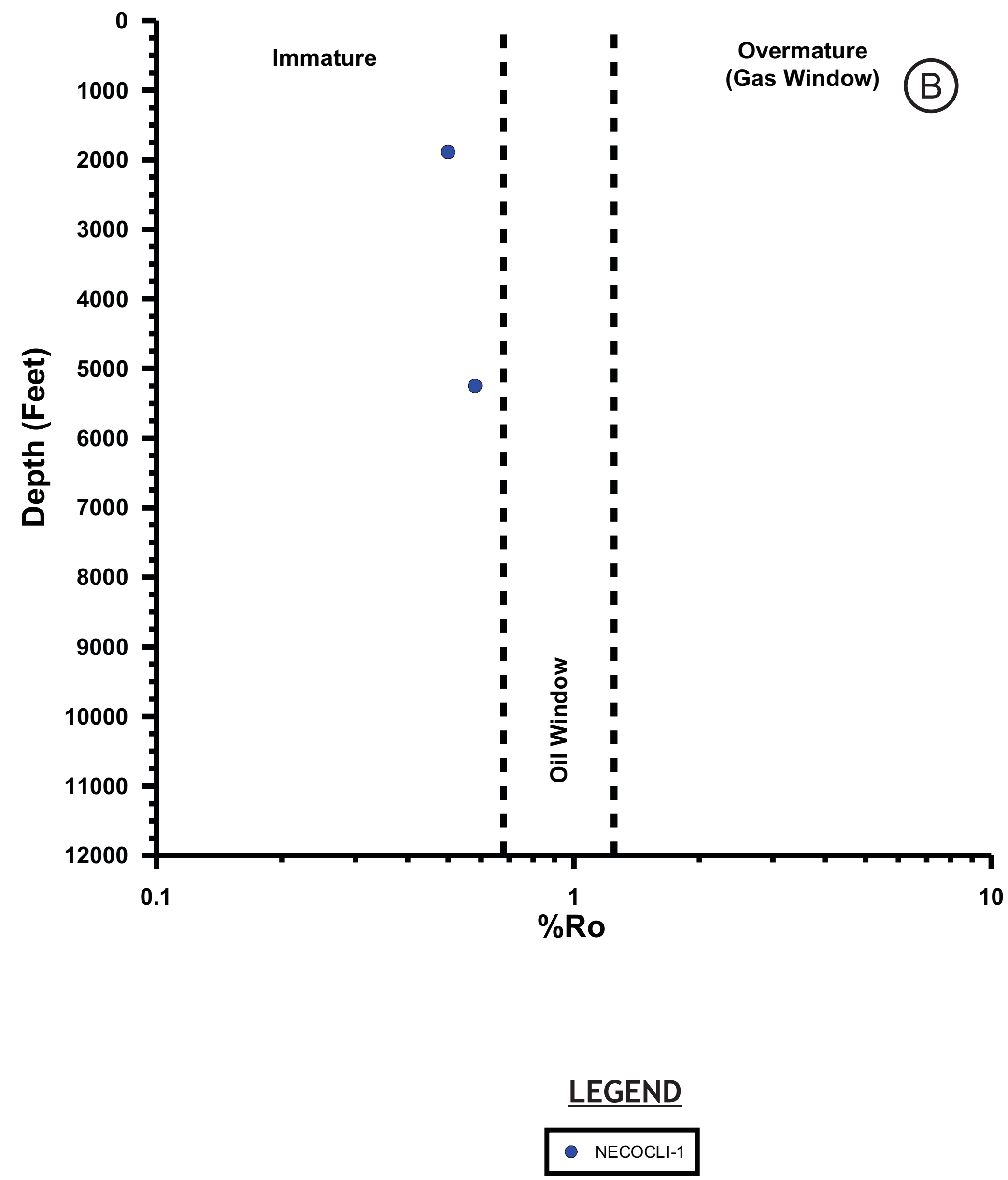
- The data obtained from pyrolysis Rock-Eval of rock samples for Hydrogen Index (HI) and S2 peak, indicate that the potential source rocks have poor generation potential in the basin (HI < 200mg HC/g TOC and S2 < 5 mg HC/g rock) (Figure A).

- The Oxygen Index vs Hydrogen Index diagram (Van Krevelen diagram) shows that rock samples have type IV kerogen very poor for hydrocarbons generation (Figure B).

- The Tmax maturity parameter vs Hydrogen Index graph shows that samples are immature to early mature in the basin (Figure C).

Source Rock Characterization





- Organic content (%TOC) and S2 peak values indicate source rock oil generation potential, this graph shows that the samples have poor oil generation potential (S2 < 5 mg HC/g rock and %TOC < 1) (Figure A).

-The vitrinite reflectance (%Ro) information shows that the sedimentary sequence is immature or close to early maturity in the basin (Figure B).

The existing data is too few to drawn definite conclusions on the exploratory potential of the basin, and much more has to be gathered to have a better idea on its real prospectivity.

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APPENDIX

ANH ORGANIC GEOCHEMISTRY DATABASE DATA SOURCES

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