

PS South Caribbean Petroleum Systems: An Updated Overview*

David S. Sanabria¹ and Victor O. Ramirez¹

Search and Discovery Article #11059 (2018)**

Posted March 12, 2018

*Adapted from poster presentation given at 2017 AAPG Annual Convention & Exhibition, Houston, Texas, April 2-5, 2017

**Datapages © 2018 Serial rights given by author. For all other rights contact author directly.

¹Exploration, Ecopetrol S.A., Bogota, Colombia (victor.ramirez@ecopetrol.com.co)

Abstract

Hydrocarbon potential in the Offshore Caribbean Basin in Colombia has been proven by recent exploratory success in the region, with the hydrocarbon discoveries of Perla in 2009, Orca in 2014 and Kronos in 2015. The petroleum systems effectivity is recognized as associated with biogenic and thermogenic and processes for hydrocarbon generation (Ramirez et al., 2015). Biogenic hydrocarbons are generated from immature source rocks exposed to bacterial activity, sourced mainly from Lower to Middle Miocene shaly stratigraphic units. Recorded thermogenic hydrocarbons are generated from Eocene and Oligocene source rocks that have attained a sufficient depth of burial and thermal maturity level (Ramirez et al., 2015; Ramirez, 2007; Rangel et al., 2003). Besides Eocene, Oligocene and Miocene organic rich strata, source rocks in the Caribbean offshore basin of Colombia may include Cretaceous rocks which can be equivalent to the La Luna Formation of Maracaibo area with a kerogen type II (Yurewicz et al., 1987).

Source rocks of Tertiary units have been identified as type III, which give the basin its predominantly gas-prone character. Recent data and Ecopetrol interpretations (Ramirez et al., 2015; Ramirez et al., 2012) have allowed us to postulate a Late Cretaceous source rock in the deep offshore area in the western part of the basin in preserved stratigraphic sections associated with the South Caribbean Deformed Belt and in hemi-graben type depocenters in the Caribbean Plate. Upper Cretaceous source rocks have been identified in DSPD and ODP locations in the deep Colombia Basin (Moore and Fahlquist, 1976). Heat flow data, thermal regime interpretations and 1D and 2D modeling can constrain the generation potential of these potential Mesozoic source rocks. The integration of a regional geologic framework, based on information associated with the different elements of the petroleum system from both local scale and basin scale (Caribbean-South America geology) along with thermal history data and petroleum system modeling can provide a better understanding of petroleum systems processes and the associated hydrocarbon potential in this frontier offshore area of Colombia.

Selected References

Meschede, M., and W. Frisch, 1998, A plate tectonic model for the Mesozoic and Early Cenozoic history of the Caribbean plate: Tectonophysics, v. 296, p. 269-291.

Moore, G.T., and D.A. Fahlquist, 1976, Seismic profile tying Caribbean DSDP Sites 153, 151, and 152: Geol. Soc. Am. Bull., v. 87, p. 1609-1614.

Ramirez, Victor, Luz Stella Vargas, Claudia Rubio, Helga Nino, and Oswaldo Mantilla, 2015, Petroleum systems of the Guajira Basin, Northern Colombia, chapter 15, Petroleum geology and potential of the Colombian Caribbean Margin: AAPG Memoir 108, 2015, p. 399-430.

Rubio, R., and V. Ramirez, 2000, Evaluacion regional de la Cuenca de La Baja Guajira, Informe interno, Ecopetrol, Bogota.

SOUTH CARIBBEAN PETROLEUM SYSTEMS, AN UPDATED OVERVIEW

DAVID SANABRIA AND VICTOR RAMIREZ
Ecopetrol S.A. - Exploration Vicepresidency

ABSTRACT

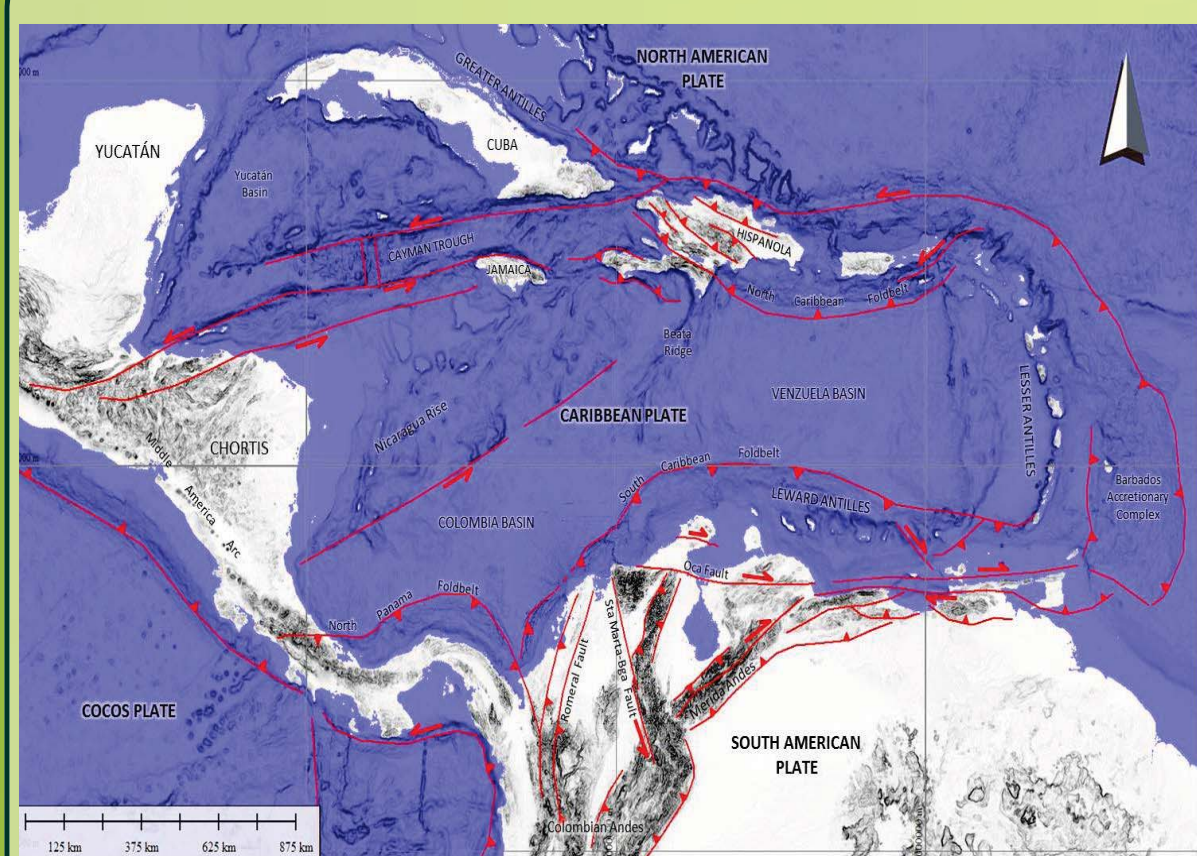
Hydrocarbon potential in the Offshore Caribbean Basin in Colombia has been proven by recent exploratory success in region, with the hydrocarbon discoveries of Perla in 2009, Orca in 2014 and Kronos in 2015. The petroleum systems effectivity is recognized as associated to biogenic and thermogenic and processes for hydrocarbon generation (Ramirez et al, 2015). Biogenic hydrocarbons are generated from immature source rocks exposed to bacterial activity, sourced mainly from Lower to Middle Miocene shaly stratigraphic units. Recorded thermogenic hydrocarbons are generated from Eocene and Oligocene source rocks that have attained a sufficient depth of burial and thermal maturity level (Ramirez et al , 2015; Ramirez, 2007, Rangel et al., 2003).

Besides Eocene, Oligocene and Miocene organic rich strata , source rocks in the Caribbean offshore basin of Colombia may include Cretaceous rocks which can be equivalent to La Luna Formation of Maracaibo area with a kerogen type II (Yurewicz et al, 1987). Source rock of Tertiary units have been identified as type III, which give to the basin its predominantly gas prone character.

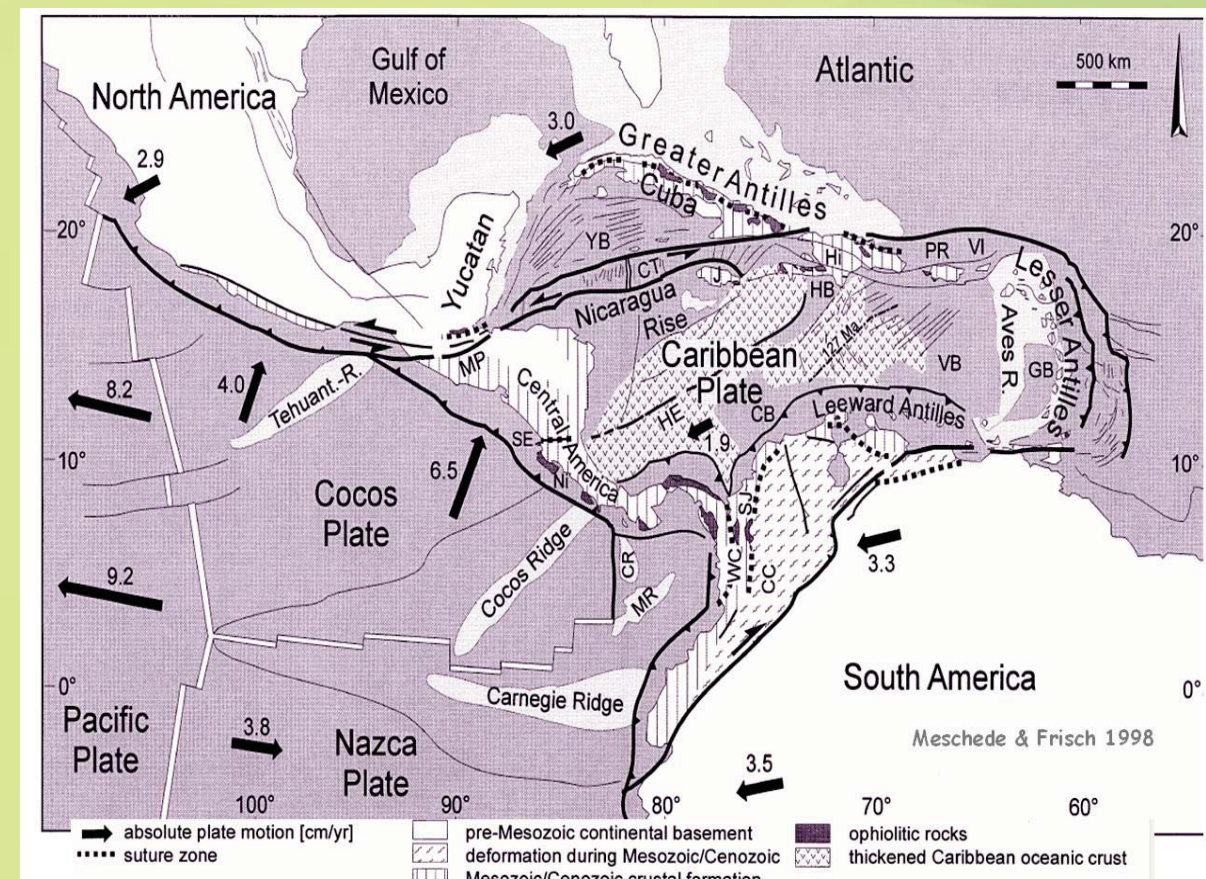
Recent data and Ecopetrol's interpretations (Ramirez et al, 2015; Ramirez et al., 2012) have allowed to postulate a Late Cretaceous source rock in the deep offshore area in the western part of the basin in preserved stratigraphic sections associated to the South Caribbean Deformed Belt and in hemigraben type depocenters in the Caribbean Plate. Upper Cretaceous source rocks have been identified in DSPD and ODP locations in the deep Colombia Basin (Moore and Fahlquist, 1976). Heat flow data, thermal regime interpretations and 1D and 2D modeling can constrain the generation potential of these potential Mesozoic source rocks.

The integration of a regional geologic framework, based on information associated to the different elements of the petroleum system from both local scale and basin scale (Caribbean-South America geology) along with thermal history data and petroleum system modeling can provide a better understanding of petroleum systems processes and the associated hydrocarbon potential in this frontier offshore area of Colombia.

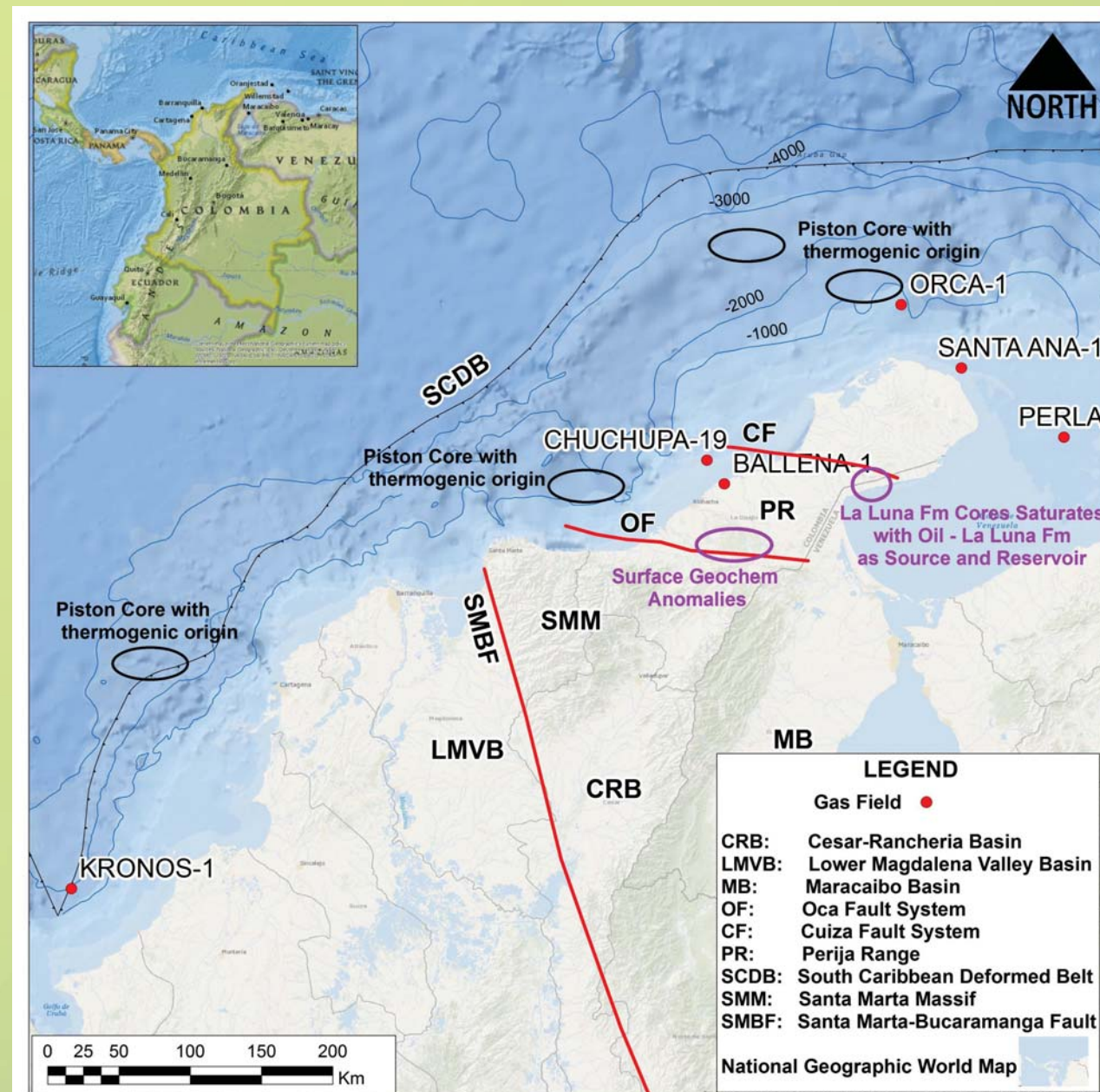
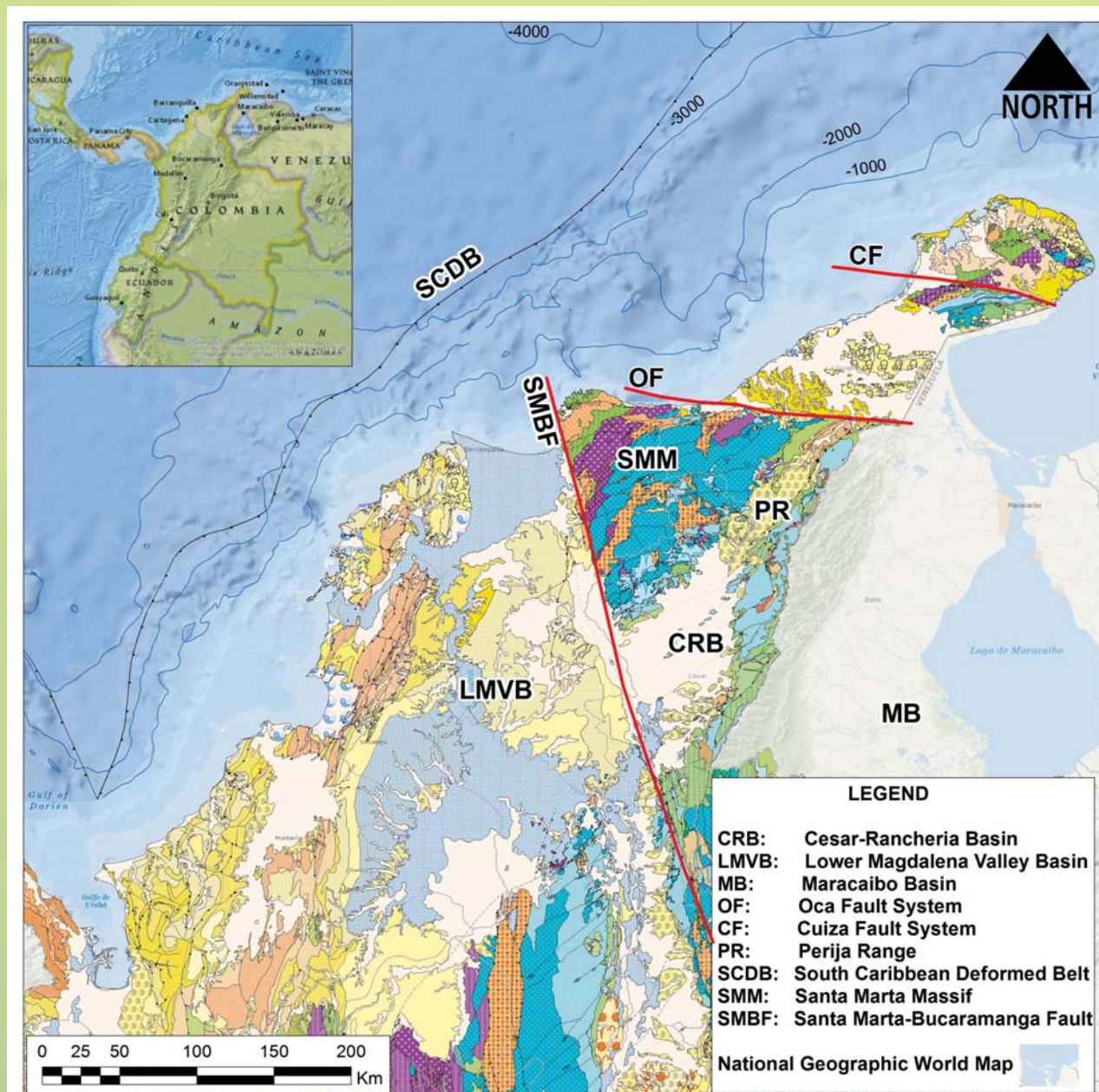
TECTONIC SETTING OF THE CARIBBEAN



The Colombian Caribbean offshore is the current boundary between the South American and Caribbean plates. The most important geological features are: the Hess escarpment, the Beata Ridge, the Aves Ridge and the Caribbean Deformed Belt. The occurrence of several deformation events results in a geologically complex area, characterized by diverse structural styles such as thrust belts and rotated blocks controlled mainly by transpressive strike-slip movements related to the oblique plate convergence generated as the Caribbean Plate advances in an E-SE direction relative to the South American Plate.



REGIONAL GEOLOGY AND HYDROCARBON OCCURRENCES



SOUTH CARIBBEAN PETROLEUM SYSTEMS, AN UPDATED OVERVIEW

DAVID SANABRIA AND VICTOR RAMIREZ
Ecopetrol S.A. - Exploration Vicepresidency

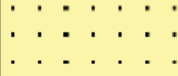





STRATIGRAPHIC RECORD

General lithologic record and stratigraphic column of the Guajira Basin, with detail in the units of interest for this work (from Rubio and Ramirez, 2000).

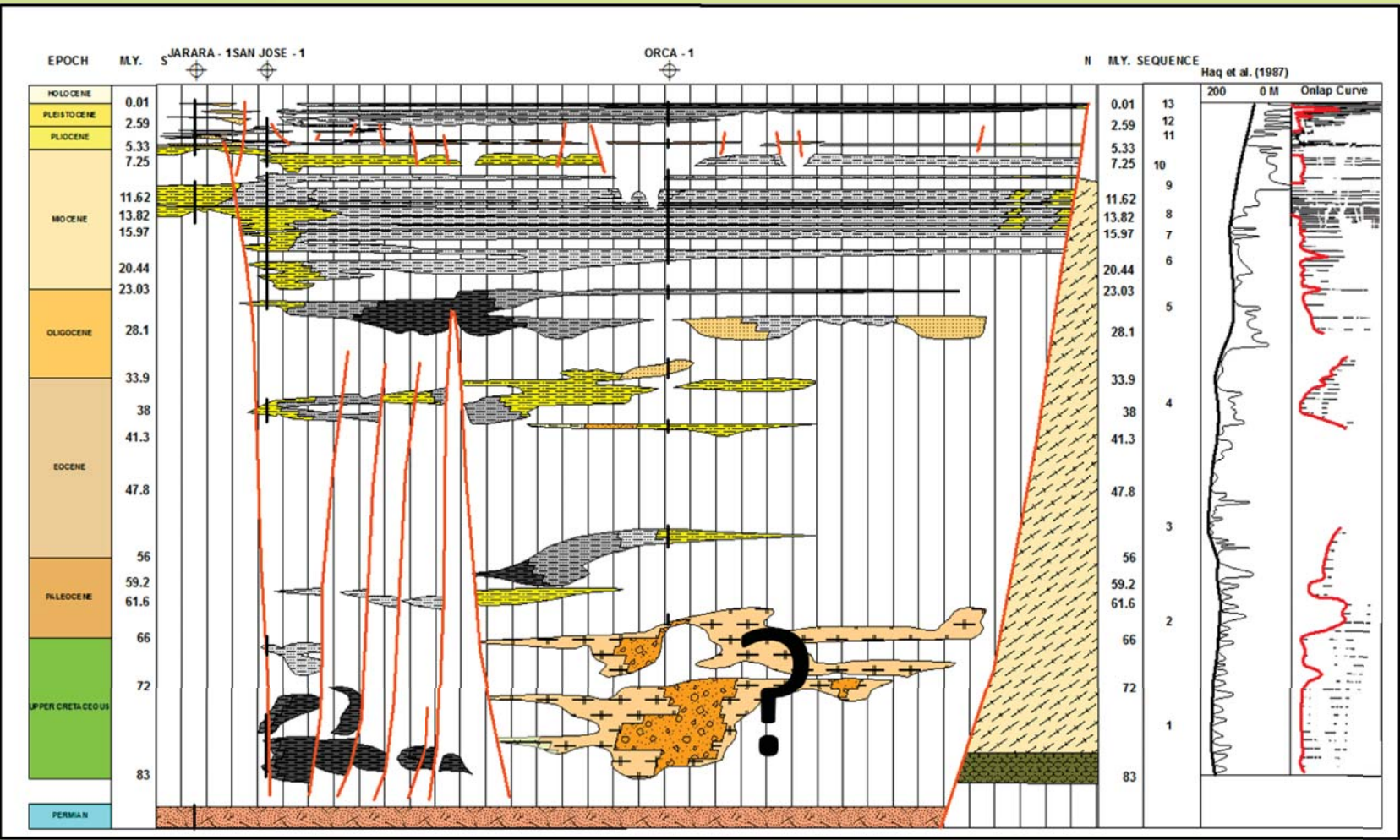
PERIODO	EPOCA	SUBEPOCA	EDAD	Formación	Tectono secuencias (Sismica)
Q	Pleistoceno				TNII
NEOGENO	Plioceno	Tardío	Piacenziano	Castilletes	TNII
		Temprano	Zancleano		
			Messiniano		
	Mioceno	Tardío	Tortoniano	Jimol	TNI
		Medio	Serravalliano		
		Langhiano			
PALEOGENO	Oligoceno	Temprano	Burdigaliano	Uitpa	TPIII
			Aquitaniano		
			Chattiano		
	Eoceno	Tardío	Priaboniano	Macarao	TPII
		Medio	Bartoniano		
		Lutetiano			
CRETACICO	Paleoceno	Temprano	Ypresiano	Guaralamai	TPI
		Medio	Thantiano		
		Temprano	Selandiano		
	Tardío		Daniano	La Luna	TKI
			Maastrichtiano		
			Campaniano		
JURASICO	Tardío		Santoniano	Maraca	TKI
			Coniaciano		
			Turoniano		
	Medio		Cenomaniano	Cogollo Inferior	TKI
			Albiano		
			Aptiano		
TRIASICO	Tardío		Barremiano	Cuisa shale	?
			Hauteriviense		
			Valanginiano		
	Medio		Berriasiano	Chinapa	?
			Tithoniano		
			Oxfordiano		
TRIASICO	Tardío		Triasico	Cajú	?
			Triasico		
			Triasico		
	Medio		Triasico	Cheterlo	?
			Triasico		
			Triasico		
TRIASICO	Tardío		Triasico	Uipana	?
			Triasico		
			Triasico		
	Medio		Triasico	Rancho Grande	?
			Triasico		
			Triasico		
TRIASICO	Tardío		Triasico	Basamento	Bas
			Triasico		
			Triasico		
	Medio		Triasico		
			Triasico		
			Triasico		

* Source rock

General lithologic record and stratigraphic column of the Sinu-San Jacinto Fold Belt. (From Ecopetrol 2016).

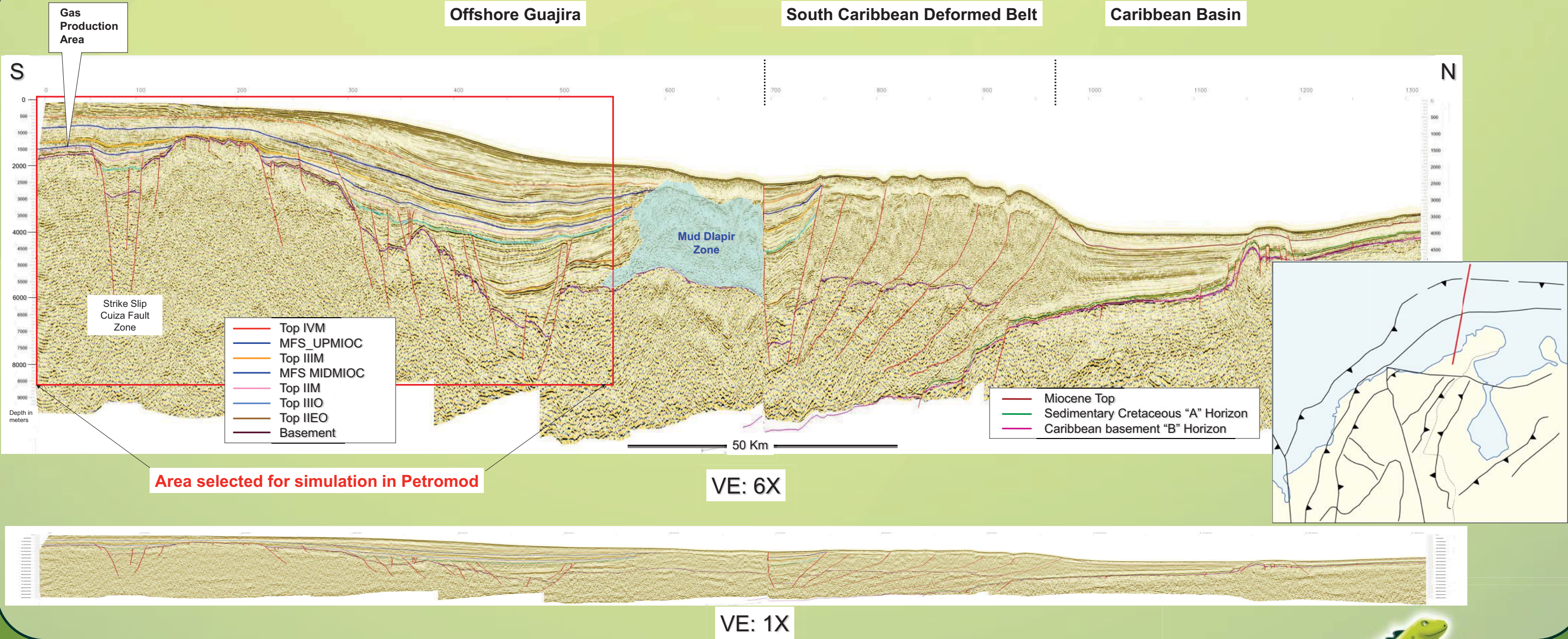
Eon	Era	Periodo	Epoca	Edad	Unidad	Litología
Fanerozoico	Cenozoico	Neogene	Pleistoceno	Superior	Fm. Corpa	
				Inferior		
			Plioceno	Superior	Fm. Morrocoy - El Pantano	
				Inferior		
		Mioceno	Superior	Fm. Pajuil		
			Medio			Fm. Floresanto
			Inferior	Fm. Pavo/ M. Campano		
			Superior			Fm. Maralu
		Paleogene	Oligoceno	Inferior	Fm. Resbalosa/ Manantial	
				Superior		Fm. La Risa/ Toluviejo
			Eoceno	Medio	Fm. Chert de Candelaria	
				Inferior		Fm. San Cayetano
		Paleoceno	Superior			
			Inferior			
		Cretáceo	Superior	Fm. Cansona		
		Basamento				

CHRONOSTRATIGRAPHIC FRAMEWORK



Regional Wheeler Diagrams prepared from the integration of available biostratigraphic and chronostratigraphic records in the Guajira Basin. (Mantilla et., al 2015).

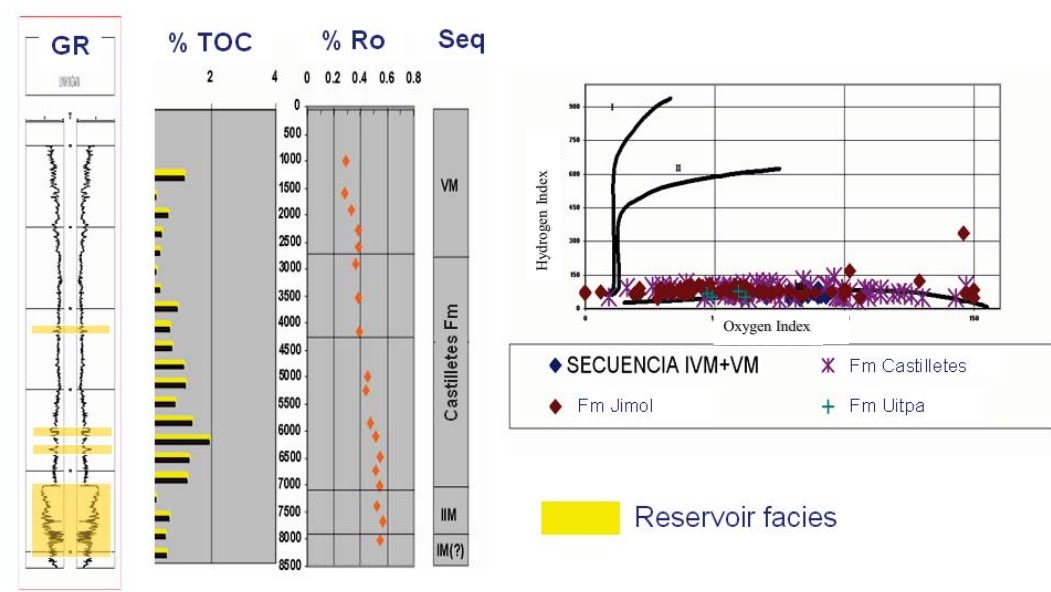
STRUCTURAL INTERPRETATION



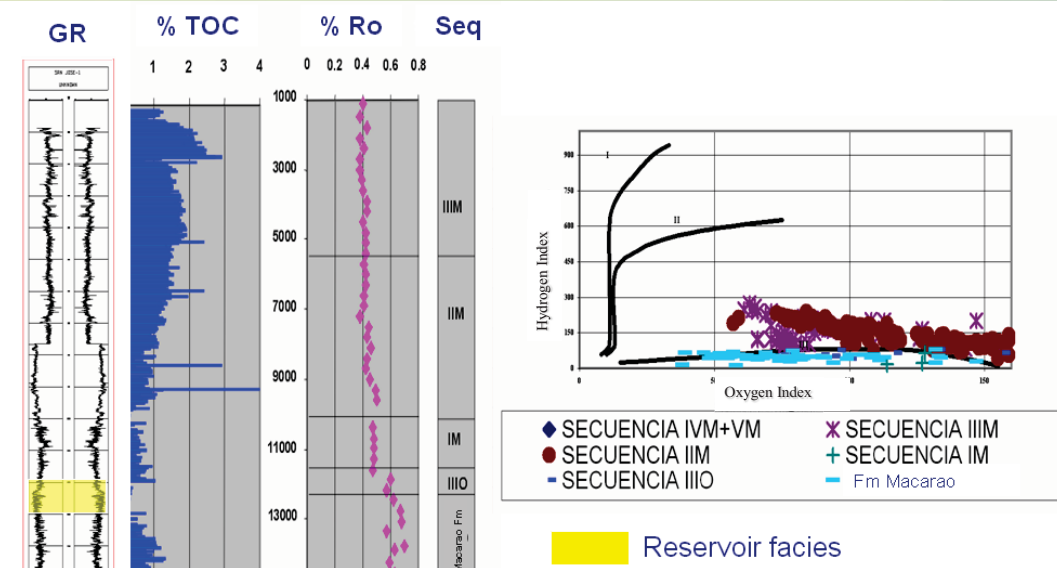
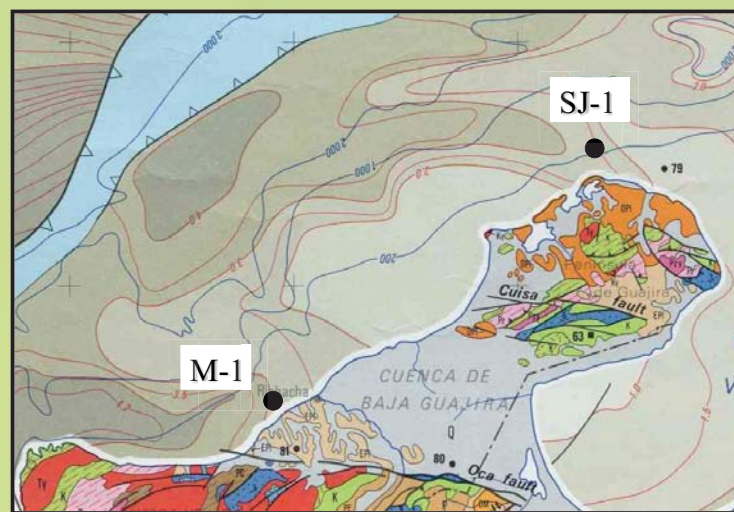
SOUTH CARIBBEAN PETROLEUM SYSTEMS, AN UPDATED OVERVIEW

DAVID SANABRIA AND VICTOR RAMIREZ
Ecopetrol S.A. - Exploration Vicepresidency

SOURCE ROCK QUALITY AND MATURITY LEVEL



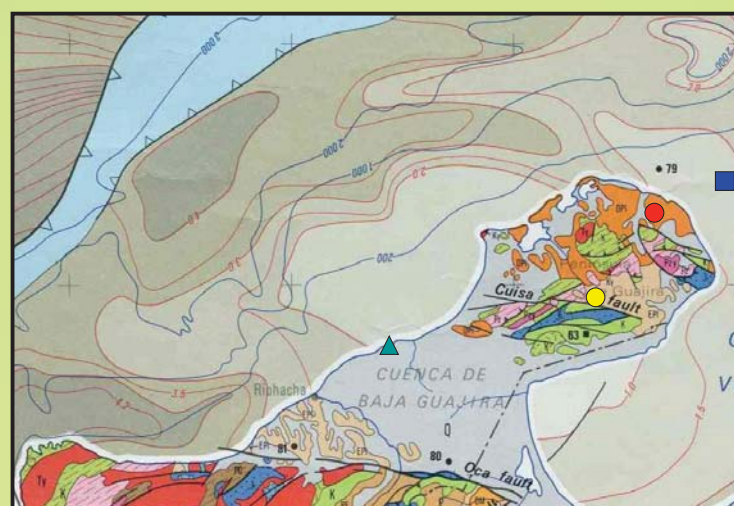
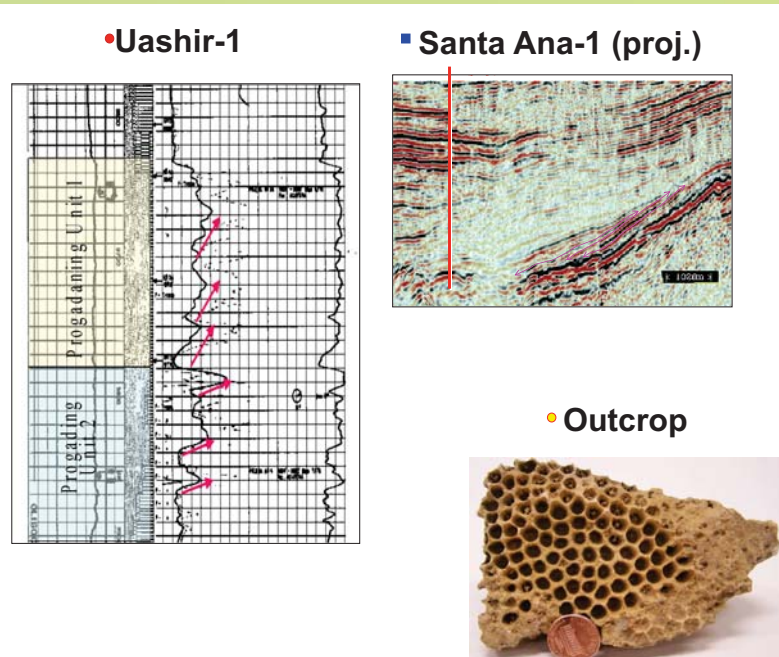
Geochemical profile of Epehin-1 well and Van Krevelen type diagram for Mero-1 well.



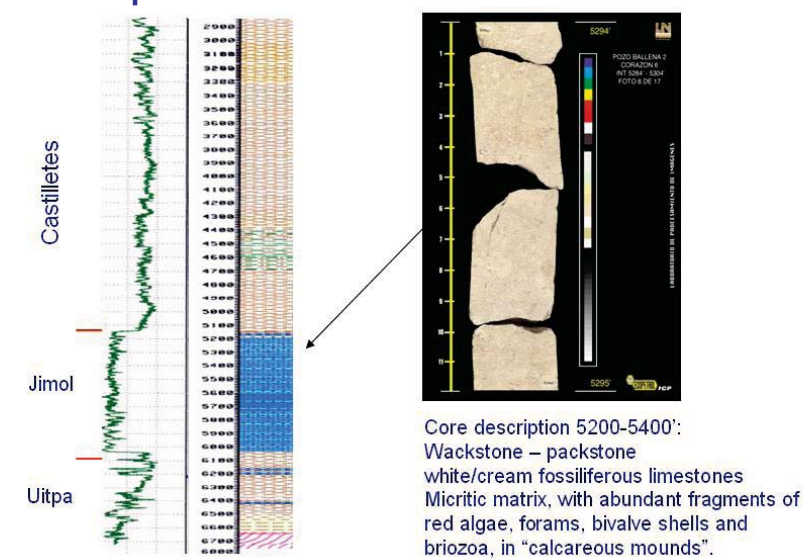
Geochemical profile and Van Krevelen type diagram from San Jose-1 well.

RESERVOIR QUALITY AND DISTRIBUTION

Oligocene shallow platform and deltaic environments. Uashir-1 and Santa Ana-1 (Olaya et Al., 2003)

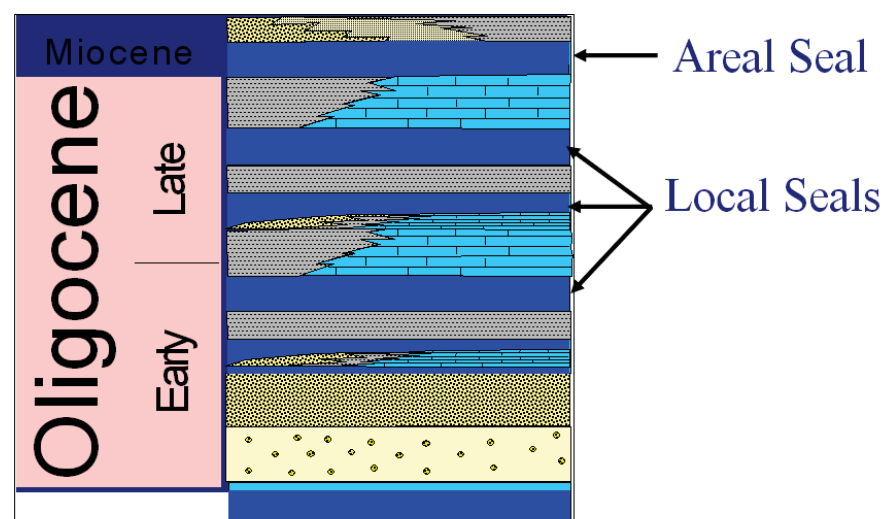


Gas producer well



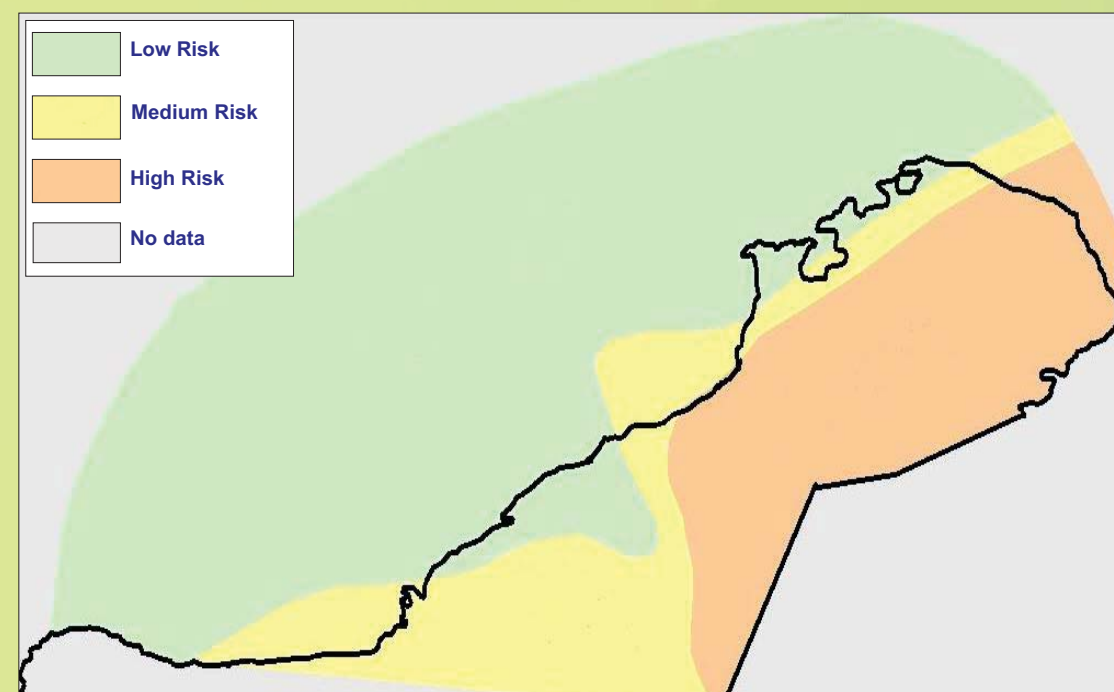
Lower Miocene Jimol reservoir.

SEAL ROCK OCCURRENCE

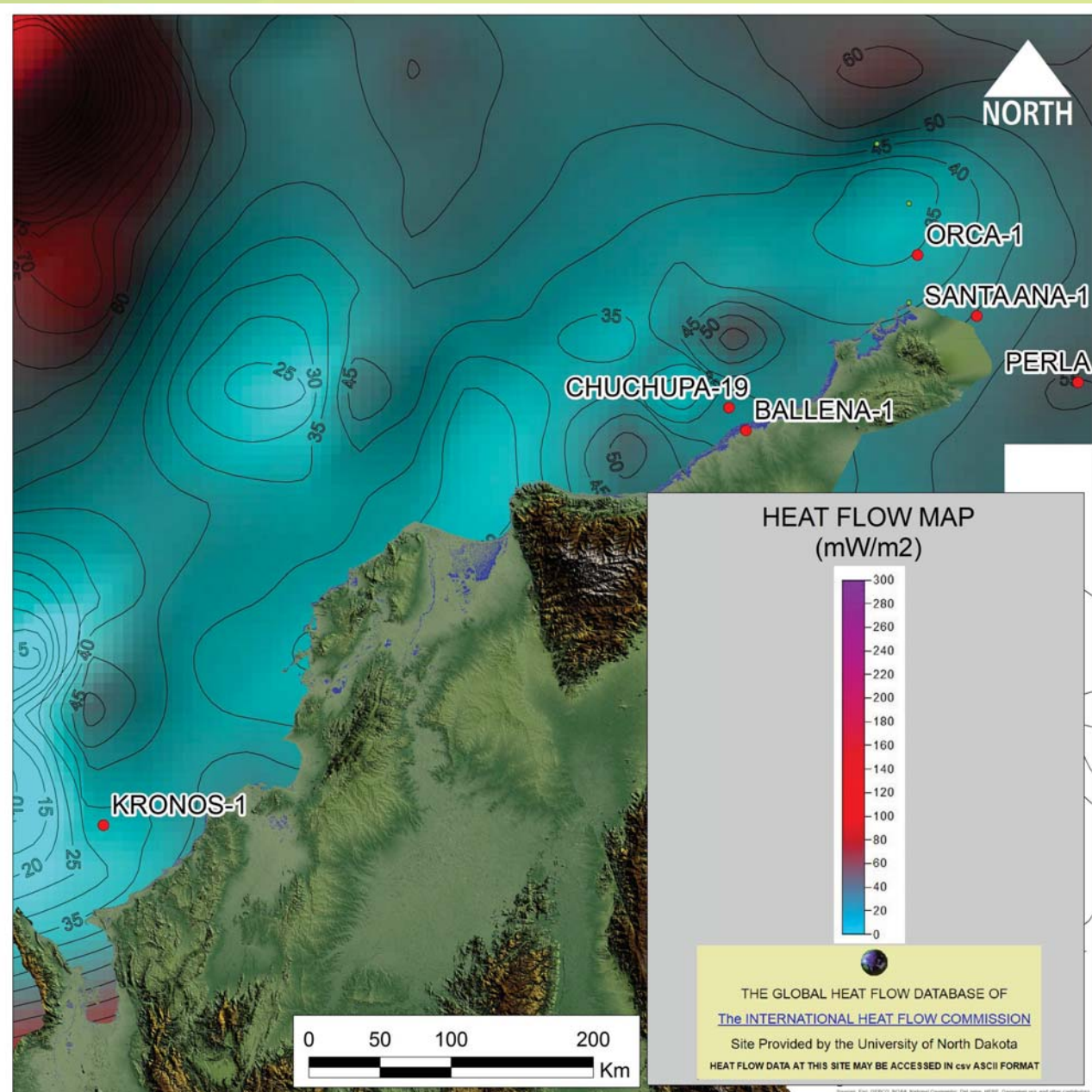


Local and areal seals for the Oligocene reservoirs in Alta Guajira

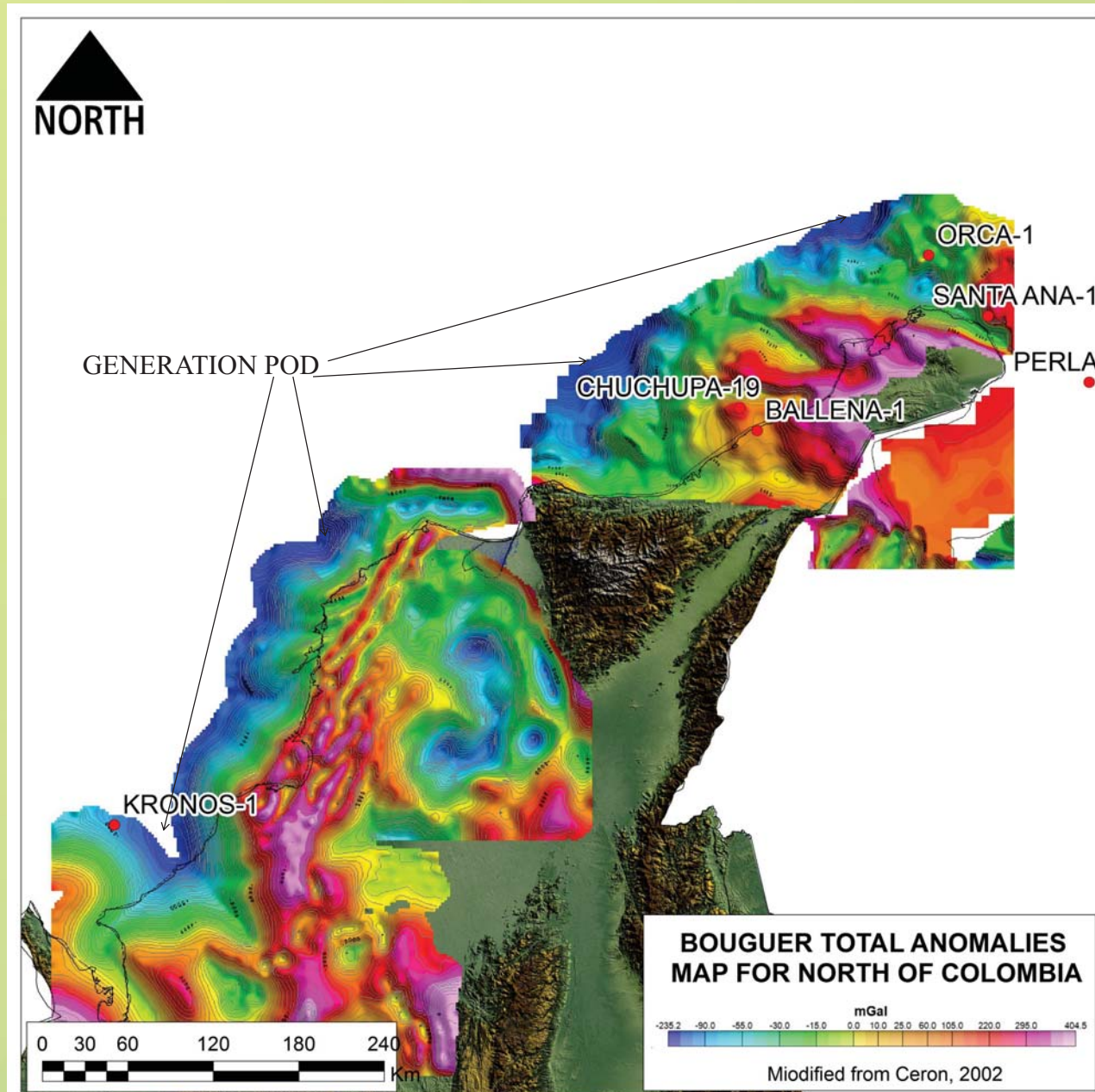
Seal risk evaluated for the Sequences IIIM and IVM by Ramirez et Al. (2004) according to capacity (capillary pressure), integrity (clay composition and framework) and geometry (thickness and areal extension).



HEAT FLOW AND GENERATION PODS



The Guajira Basin is in a region that shows a range of Heat Flow between 20 and 85 mW/m², values that are consistent with the relatively low thermal gradient calculated by Rubio and Ramirez (2000) from borehole temperatures.



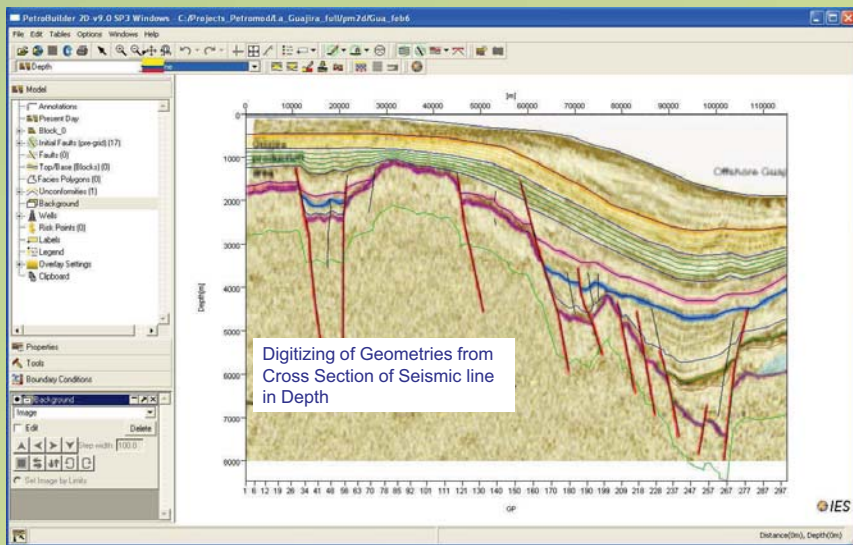
Gravimetric map showing the depocenters in the Caribbean.

SOUTH CARIBBEAN PETROLEUM SYSTEMS, AN UPDATED OVERVIEW

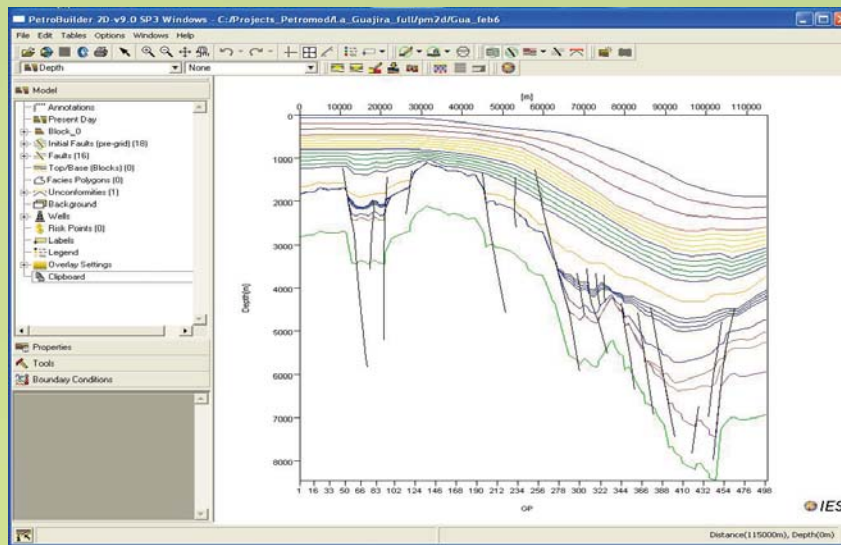
DAVID SANABRIA AND VICTOR RAMIREZ
Ecopetrol S.A. - Exploration Vicepresidency

PETROLEUM SYSTEMS MODELING

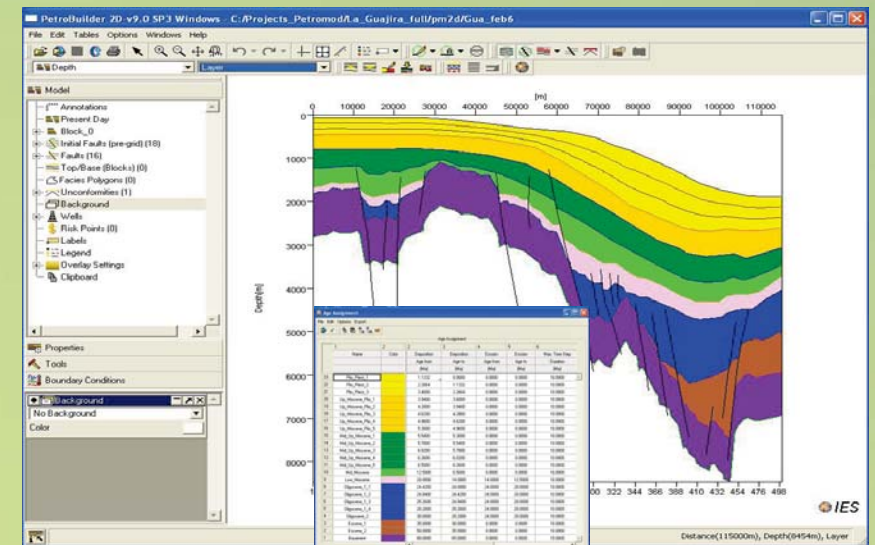
Geologic Model Built from Seismics



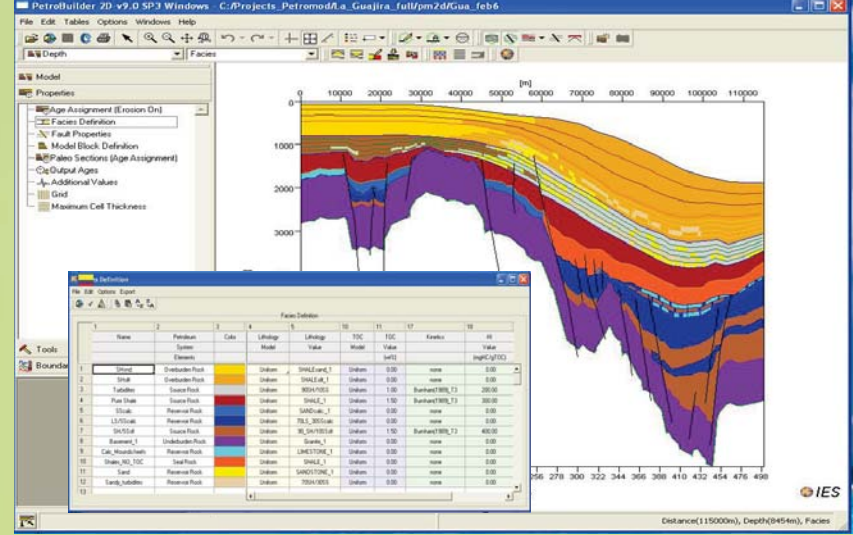
Scaled Geometry of Surfaces and Faults



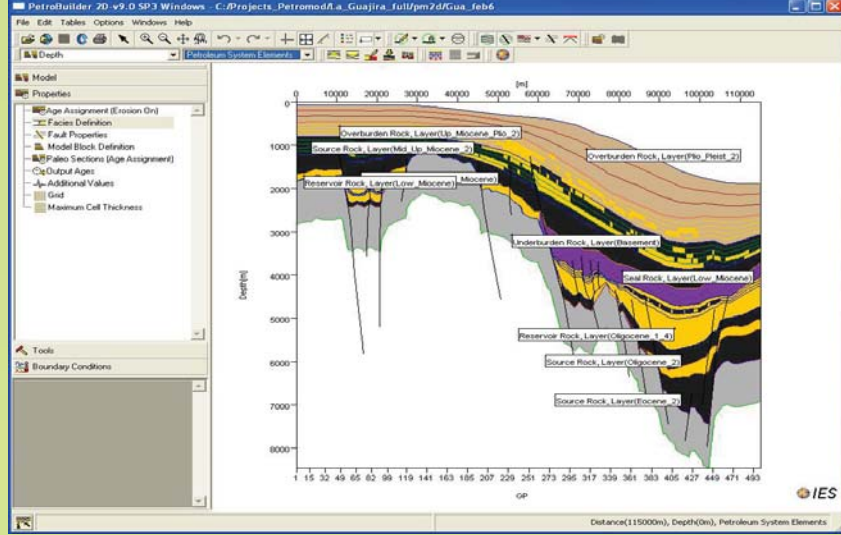
Horizons ID and Assignment of Ages



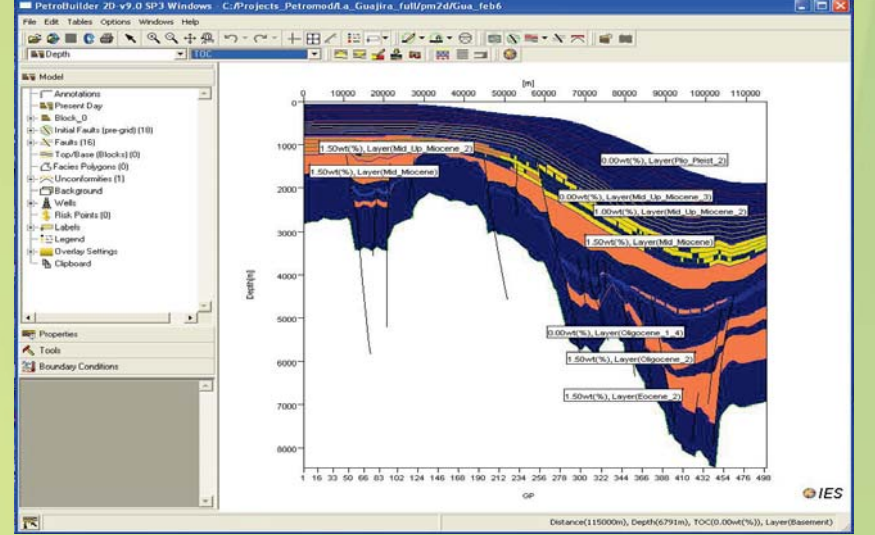
Assignment of Lithologies and Facies



Definition of Petroleum System Elements

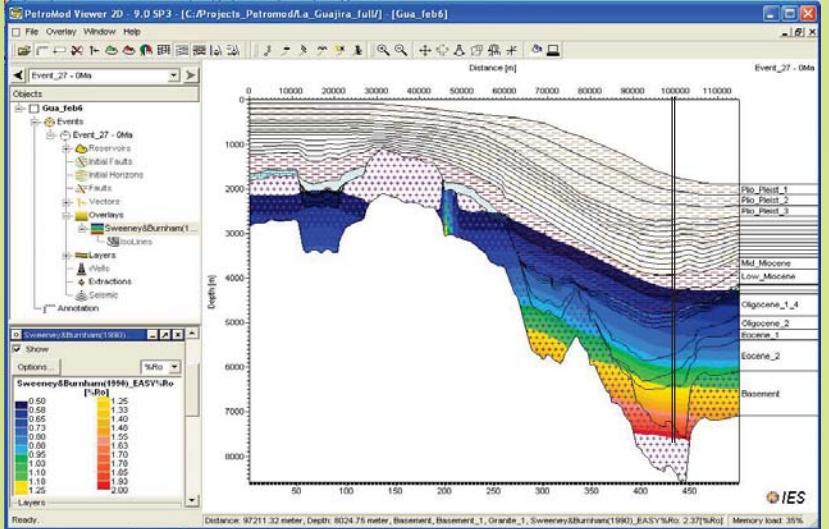


Definition of Source Rock Distribution

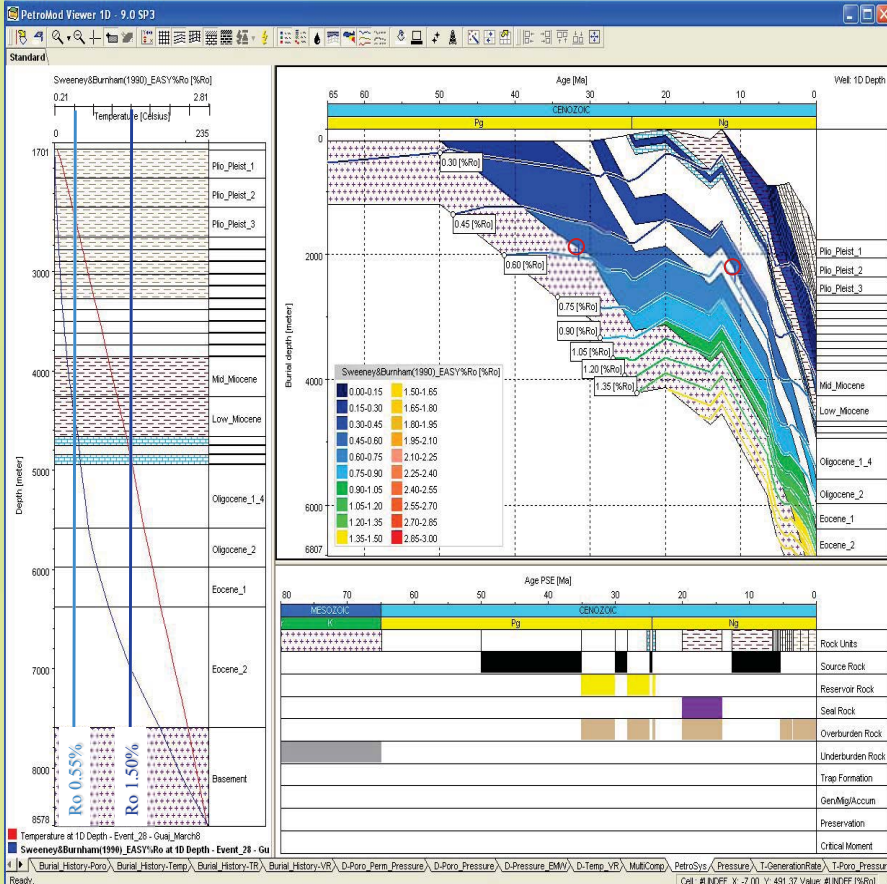


PETROLEUM SYSTEMS SIMULATION

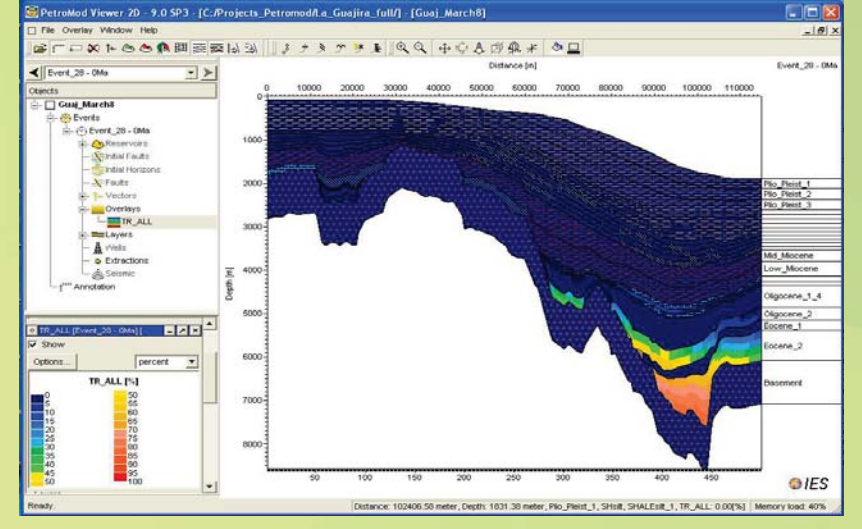
Maturity Simulation



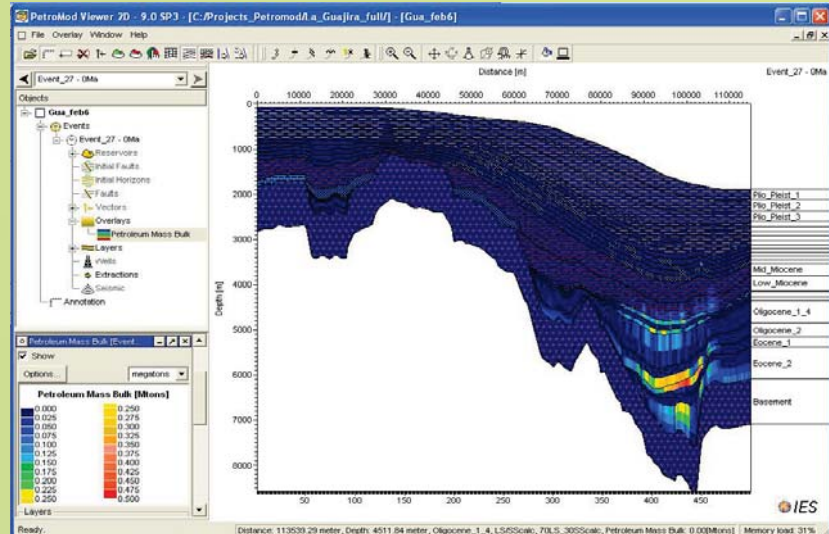
Pseudo well- Burial history 1D extraction



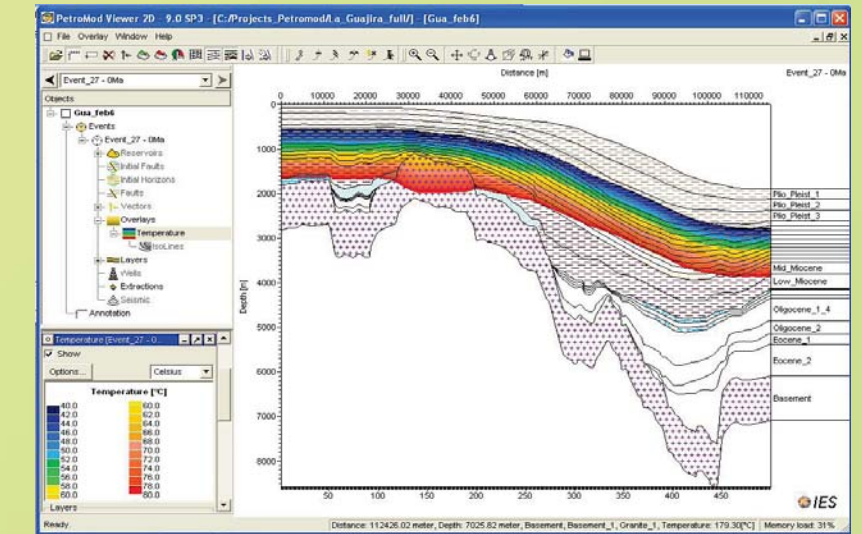
Transformation Rate Simulation



Generation Simulation



Simulation of Biogenic activity window

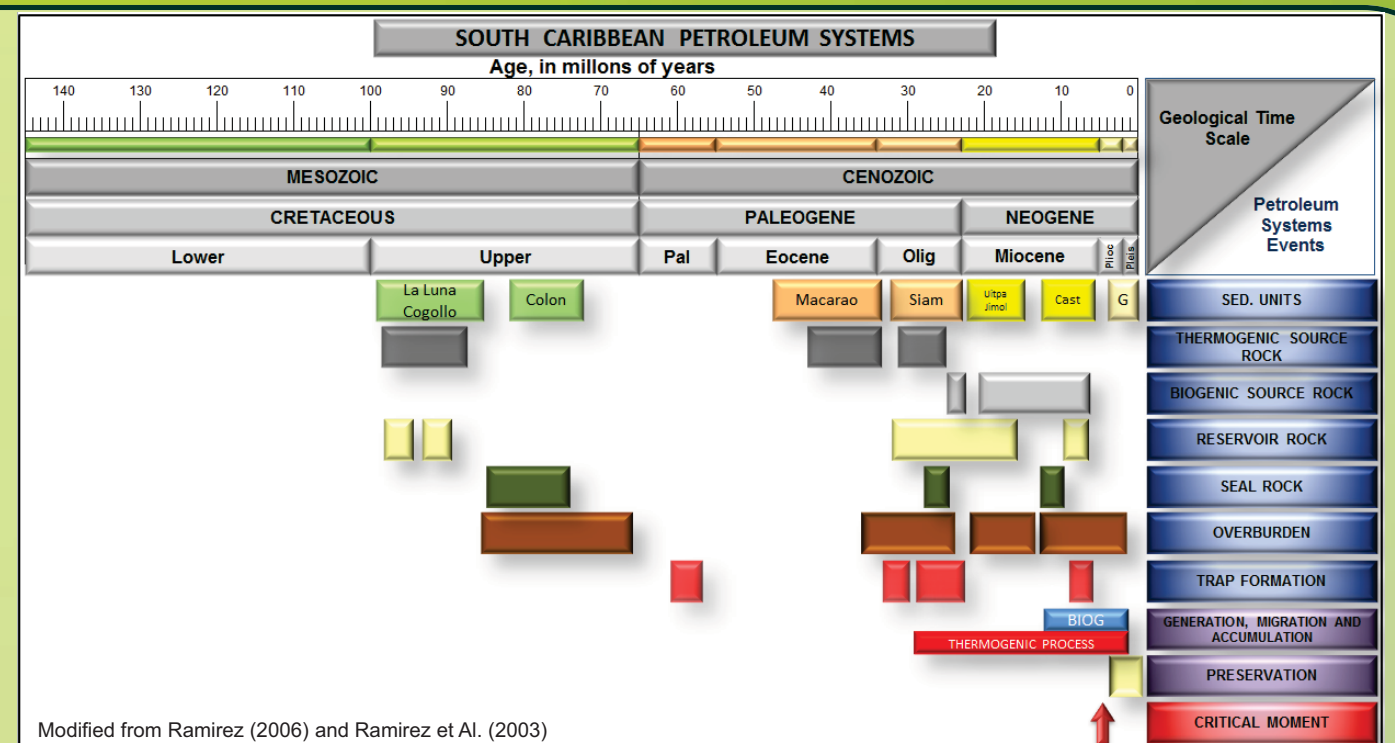


The Eocene source rocks reached the maturity window at 32 m.a., while the Oligocene source rocks only reached maturity by 12 m.a. According to the modeling, the Middle to Upper Miocene source rock have not reach thermal maturity. Presently, Cenozoic mature source rocks in the Guajira Basin are buried at depths greater than 13000'.

PETROLEUM SYSTEMS DISTRIBUTION

Modeling and simulation of the petroleum systems in the Guajira Basin show a clear distinction between biogenic and thermogenic generation processes. The gas fields are fed mainly from Middle to Upper Miocene source rocks which have not reached thermal maturity and are buried in the "bacterial activity window (40-80 °C)" since 7 m.y. ago. Eocene and Oligocene source rocks reached maturity 32 m.a. and 12 m.a. respectively. These Cenozoic source rocks are now buried at more than 13000', and feed the thermogenic hydrocarbons occurrences recorded in the deep offshore part of the Basin. This thermogenic scenario, along with recently recognized high resolution geochemical evidences, provides a framework for exploration of deep offshore pre-Miocene to Mesozoic objectives in the Guajira Basin.

P.S.
Events
chart



Petroleum Systems Regional Distribution

