

# **Changes in Eocene-Miocene Shallow-Marine Carbonate Factories along the Tropical Southeast Circum-Caribbean Responded to Major Regional-Global Environmental and Tectonic Events\***

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## **Abstract**

Changes in the factory of Cenozoic tropical marine carbonates have been long attributed to major variations on climatic and environmental conditions. Although important changes on the factories of Cenozoic Caribbean carbonates seem to have followed global climatic and environmental changes, the influence of tectonics on the occurrence, distribution and stratigraphy of shallow marine carbonate factories in this area is far from being well understood. Here we use sedimentologic characterization and multiple geochemical proxies to assess the influence of changing environmental conditions, tectonics and sea-level change on the development of the shallow-marine carbonate factories. During the Paleocene-early Oligocene interval, a period of predominant high atmospheric pCO<sub>2</sub>, coralline algae were the principal carbonate builders of shallow-marine carbonate successions. The predominance of coralline red algae over corals on the shallow-marine carbonate factories was likely related to high sea-surface temperatures and high turbidity. Deposition of these factories was also controlled by diachronic opening of different sedimentary basins along the SE Circum-Caribbean resulting from transpressional tectonics. Calcareous algae persisted until the middle Oligocene; a period when the drop of atmospheric pCO<sub>2</sub> allowed the appearance of corals as the main constituents of the shallow-marine carbonate factories by late Oligocene times. The late Oligocene interval is characterized by the occurrence of low-diversity patchy coralline reefs, often mixed with siliciclastics. The occurrence of these patchy coralline successions occurred along rimmed mixed siliclastic/carbonate platforms and seems to have been related to low sea level. The lower Miocene interval is characterized by the development of rimmed carbonate platforms along which high-diversity fringing coral reefs developed. The occurrence of these high-diversity coralline carbonate factories was favored by a decrease in the siliciclastic input from the continents and further decrease in sea-surface temperatures. Coral reef dominated the shallow-marine carbonate factories until the middle Miocene, when a new period of calcareous algae reefs occurred along the Caribbean. This new change was the result of major changes in the Caribbean environmental conditions, which were driven by increased continental sediment runoff resulting from the exhumation of the northern Andes.

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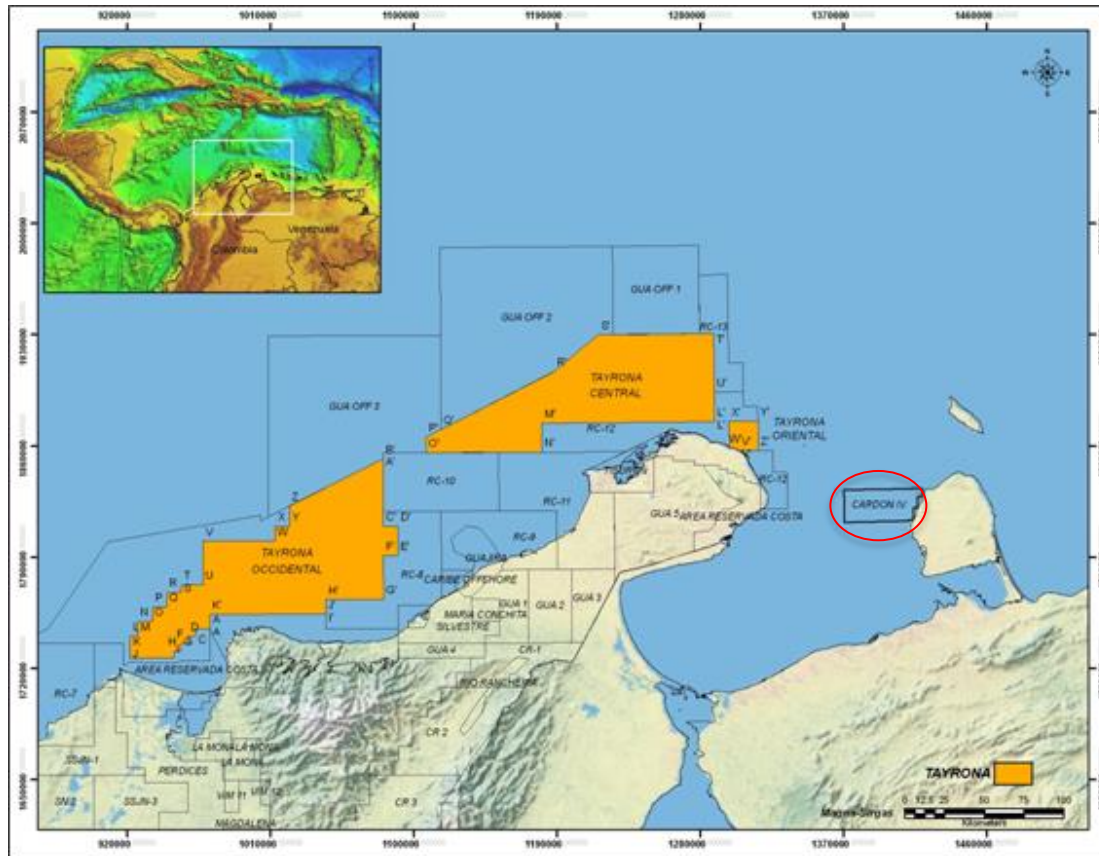
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*Camilo Montes (UNIANDES, Colombia)*

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*www.carbonateresearchgroup.org*



## “The Perla World-Class Giant Gas Field, Gulf of Venezuela: Depositional and Diagenetic Controls on Reservoir Quality in Early Miocene Carbonates”\*



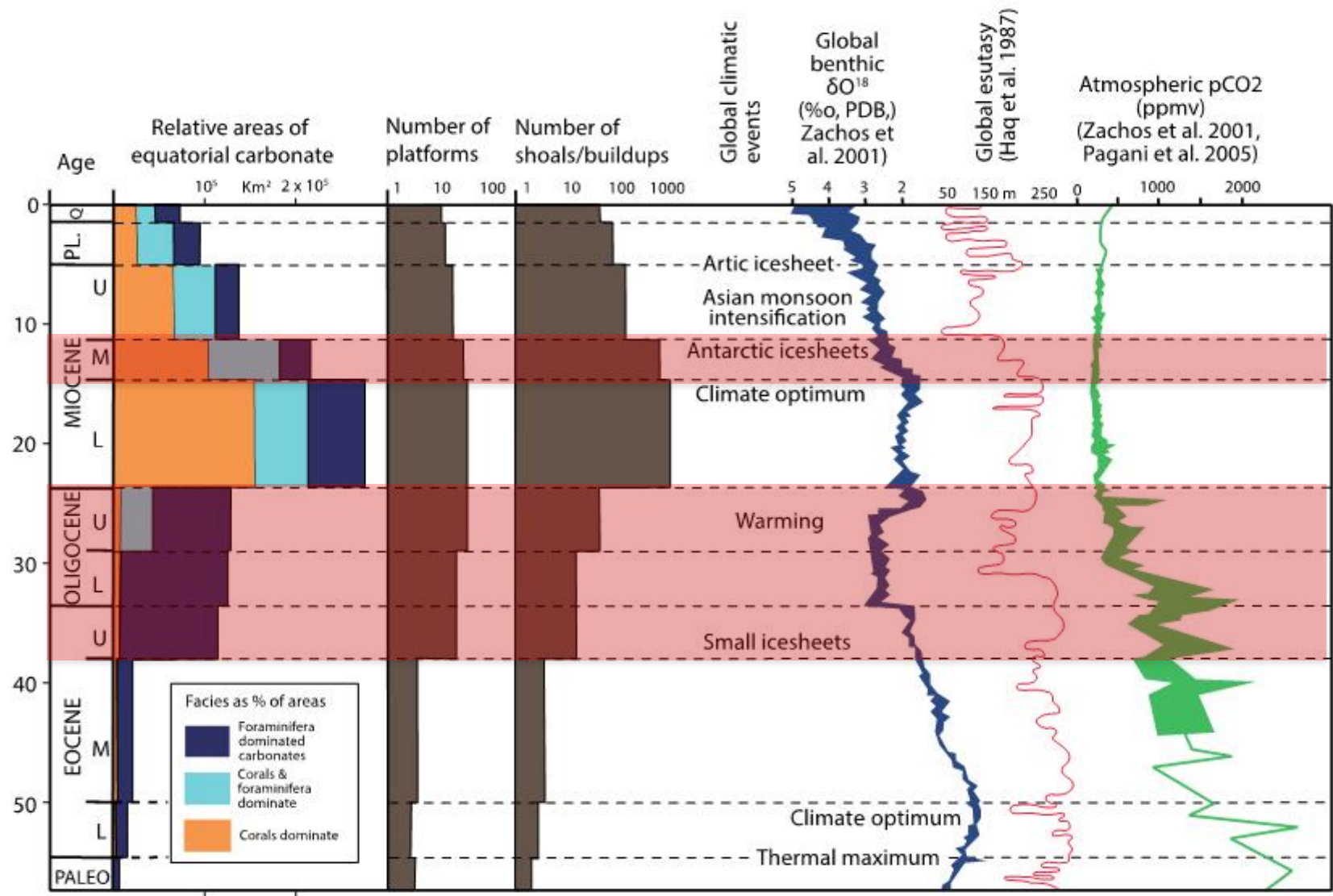
The reservoir is mainly Miocene limestone

**Dominant components are branching red algae, rhodoliths and large foraminifera.**

Minor finger corals, mollusks, barnacles, green algae, bryozoans and planktonic forms.

\*Borromeo et al. (2011)

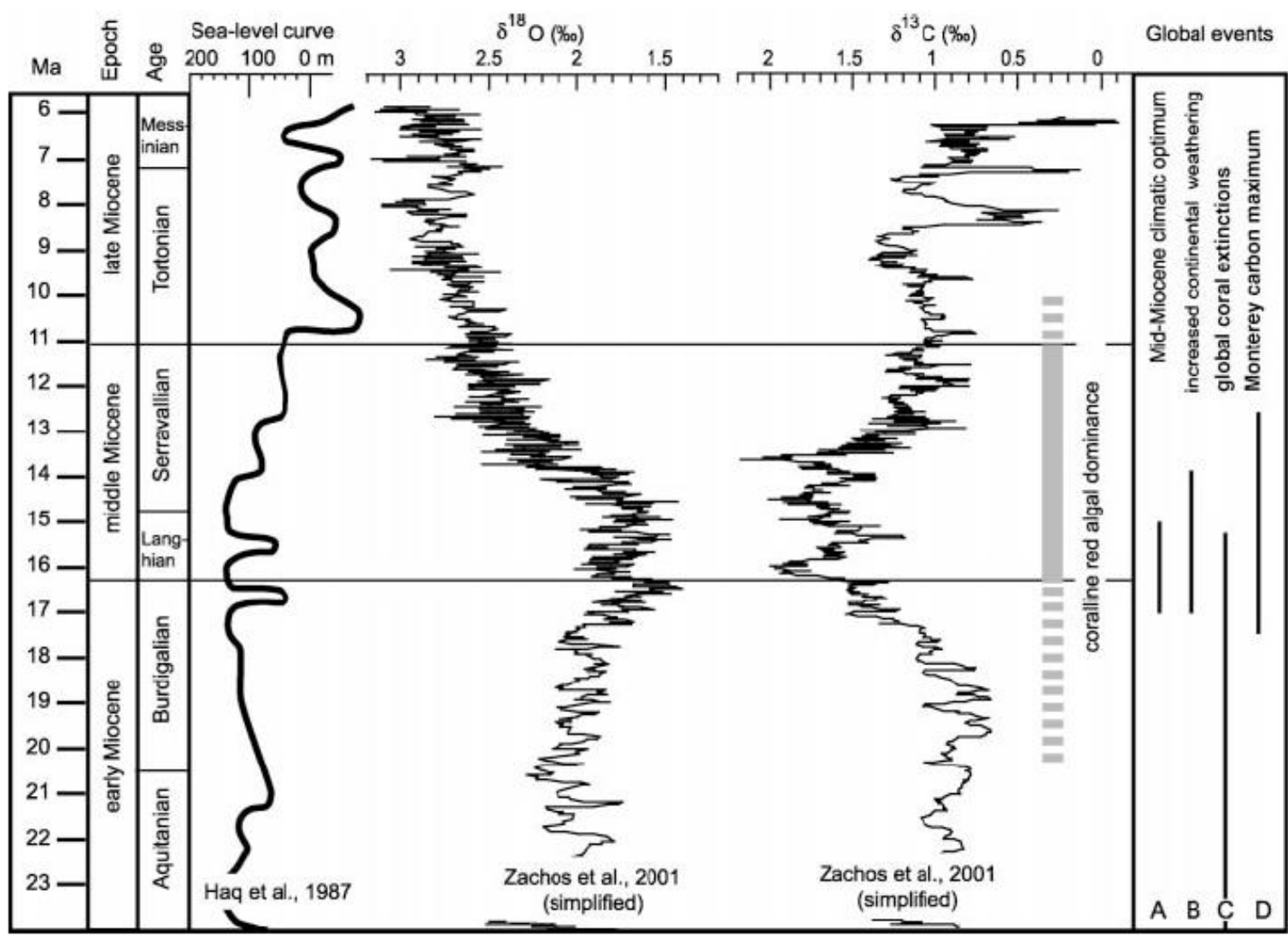
Environmental controls on carbonate factory!!!



SE Asian carbonates & events

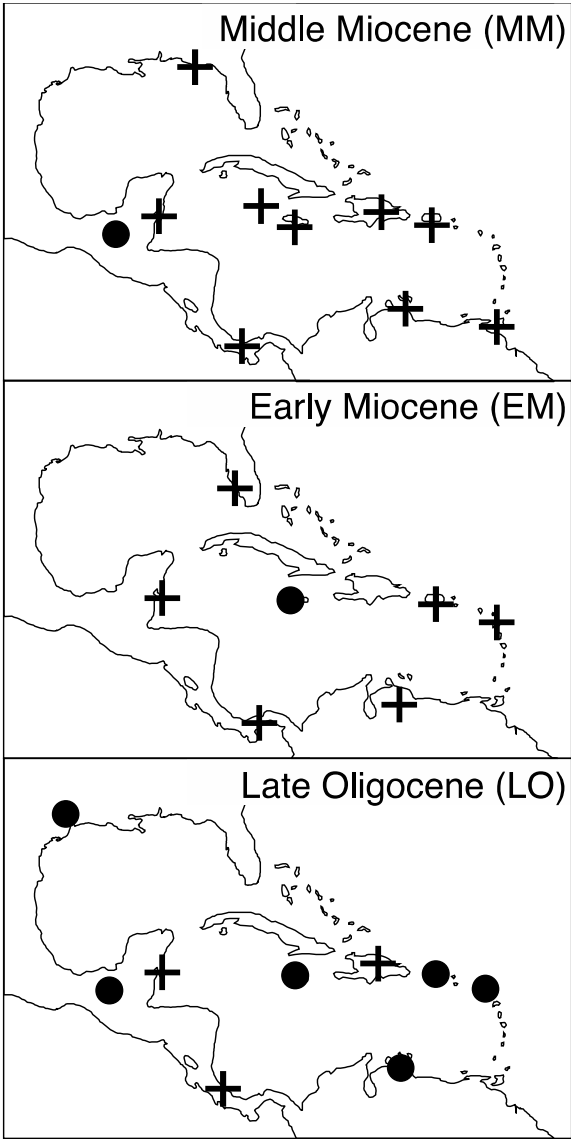
Global events

Decrease corals correspond to an increase in algae..

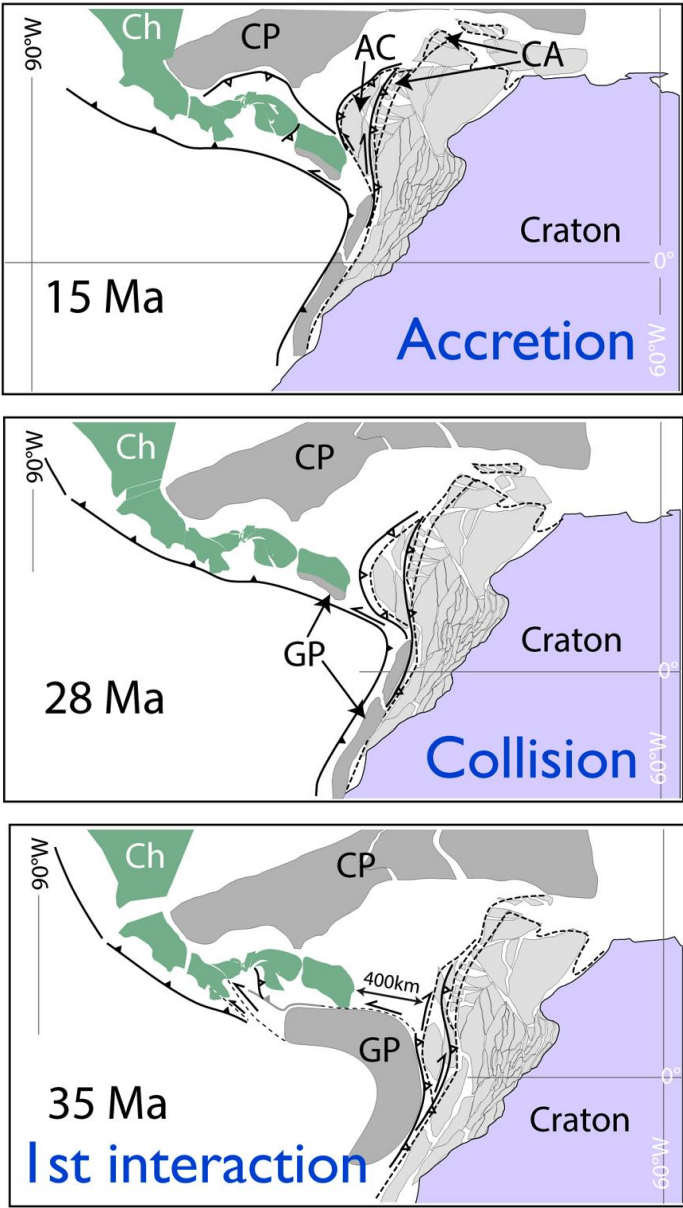




# Regional Tectonic effects?



+ Azooxanthellate (non-reef builders)  
• Zooxanthellate (reef builders) Johnson et al (2008)



Regional Tectonic effects?

Transtensional tectonics

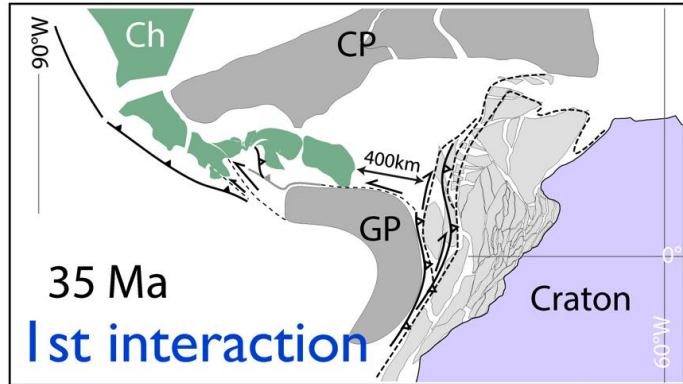
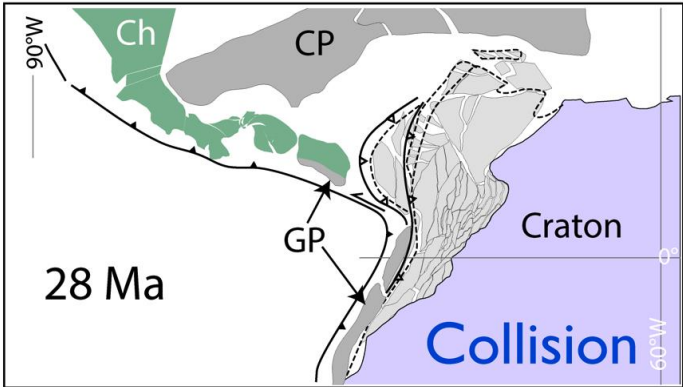
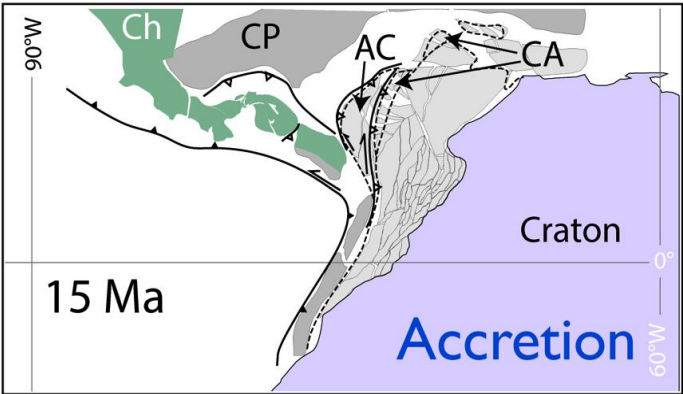
Diachronic opening of sedimentary basins

SW

NE

Age	Panama Channel Kirby et al. (2008)	Chucunaque basin (This study)	San Jacinto Fold Belt South Guzman (2007)	San Jacinto Fold Belt Central Guzman (2007)	San Jacinto Fold Belt, Central U.Caldas- ANH (2009)	Luruaco anticlinorium Guzman (2007)	Baja Guajira Lockwood (1966)	Falcon/Urumaco Quiroz et al. (2012)	Bonaire Herweijer et al. (1977)
Pleistocene	Bocas Formation					La Popa Formation			Seroi Dome Formation
Pliocene			Sincelejo Formation	Sincelejo Formation	Sincelejo Formation	Rotinet Formation	Castilletes Formation	Urumaco Formation	
Miocene			Cerrito Formation	Cerrito Formation	Cerrito Formation	Perdices-Tubara Formations	Jimol Formation	Socorro Formation	
Miocene	Cucaracha Formation	Maje Formation	Porquero Formation	Porquero Formation	Porquero Formation	Ibacho Formation	Jimol Formation	Agua Clara Formation	
Miocene	Culebra Formation		Cienaga de Oro Formation	Cienaga de Oro Formation	Cienaga de Oro Formation	Arjona Formation	Jimol/ Formation	Pecaya Fm.	San Luis Formation
Oligocene	Las Cascadas Formation	Darien Formation		Cienaga de Oro Formation	Chengue Fm.	Carmen Formation	Siamana Formation		
Oligocene				Chengue Fm.	Toluviejo Formation	Arroyo de Piedra Formation	Macarao Formation	Santa Rita Formation	Soebl Blanco Conglomerates
Eocene	Gatuncillo Formation		Tampa Formation	Toluviejo Formation	San Calletano Arroyo seco Formation	Arroyo seco Formation			
Paleocene			San Calletano Arroyo seco Formation	San Calletano Arroyo seco Formation					
Cretaceous	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement		Cretaceous basement

Volcanic rocks Continental/ Transitional siliciclastics Carbonates Deep marine siliciclastics



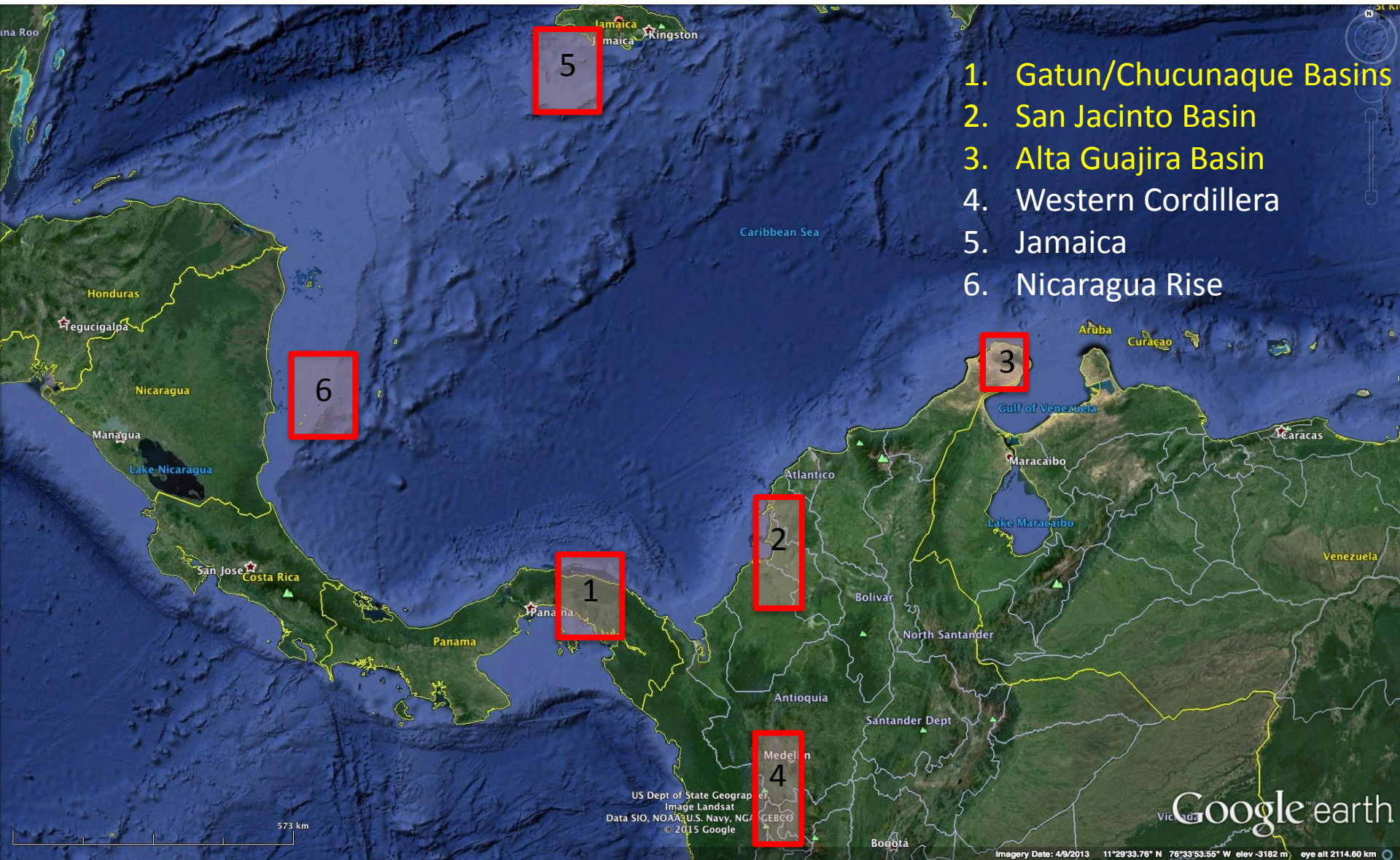
Younger Cenozoic successions

## Questions?

- Is there a Caribbean trend in Cenozoic carbonate factory?
- What controlled the evolution of Caribbean carbonate factories?
- Implications oil and gas reservoirs ?



## Study Areas



# Lithostratigraphy of the SE Circum-Caribbean

Age	Panama Channel Kirby et al. (2008)	Chucunaque basin (This study)	San Jacinto Fold Belt South Guzman (2007)	San Jacinto Fold Belt Central Guzman (2007)	San Jacinto Fold Belt, Central U. Caldas- ANH (2009)	Luruaco anticlinorium Guzman (2007)	Baja Guajira Lockwood (1966)	Falcon/Urumaco Quiroz et al. (2012)	Bonaire Herweijer et al. (1977)
Pleistocene	Bocas Formation					La Popa Formation			Seroi Dome Formation
Pliocene			Sincelejo Formation	Sincelejo Formation	Sincelejo Formation	Rotinet Formation	Castilletes Formation	Urumaco Formation	
Miocene			Cerrito Formation	Cerrito Formation	Cerrito Formation	Perdices-Tubara Formations	Jimol Formation	Socorro Formation	
	Cucaracha Formation	Maje Formation	Porquero Formation	Porquero Formation	Porquero Formation	Ibacho Formation			
	Culebra Formation		Cienaga de Oro Formation	Cienaga de Oro Formation	Cienaga de Oro Formation	Arjona Formation	Jimol/ Formation	Uitpa Fm.	Agua Clara Formation
Oligocene	Las Cascadas Formation	Darien Formation		Cienaga de Oro Formation	Chengue Fm.	Carmen Formation	Siamana Formation	Pecaya Fm.	San Luis Formation
Eocene	Gatuncillo Formation		Tampa Formation	Toluviejo Formation	San Calletano Arroyo seco Formation	Arroyo de Piedra Formation	?	?	Soebi Blanco Conglomerates
Paleocene			San Calletano Arroyo seco Formation	San Calletano Arroyo seco Formation		Arroyo seco Formation	Macarao Formation	Santa Rita Formation	
Cretaceous	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement		Cretaceous basement



Volcanic rocks



Continental/Transitional siliciclastics



Carbonates



Deep marine siliciclastics



## Panama





Lithostratigraphy of the SE Circum-Caribbean

Age	Panama Channel Kirby et al. (2008)	Chucunaque basin (This study)	San Jacinto Fold Belt South Guzman (2007)	San Jacinto Fold Belt Central Guzman (2007)	San Jacinto Fold Belt, Central U. Caldas- ANH (2009)	Luruaco anticlinorium Guzman (2007)	Baja Guajira Lockwood (1966)	Falcon/Urumaco Quiroz et al. (2012)	Bonaire Herweijer et al. (1977)
Pleistocene	Bocas Formation					La Popa Formation			Seroi Dome Formation
Pliocene			Sincelejo Formation	Sincelejo Formation	Sincelejo Formation	Rotinet Formation			
							Castilletes Formation	Urumaco Formation	
Miocene			Cerrito Formation	Cerrito Formation	Cerrito Formation	Perdices-Tubara Formations			
	Cucaracha Formation	Maje Formation	Porquero Formation	Porquero Formation	Porquero Formation	Ibacho Formation	Jimol Formation	Socorro Formation	
	Culebra Formation		Cienaga de Oro Formation	Cienaga de Oro Formation	Cienaga de Oro Formation	Arjona Formation	Jimol/ Formation	Uitpa Fm.	Agua Clara Formation
Oligocene	Las Cascadas Formation	Darien Formation		Cienaga de Oro Formation		Carmen Formation	Siamana Formation	Pecaya Fm.	San Luis Formation
					Toluviejo Formation	Chengue Fm.			
Eocene	Gatuncillo Formation		Tampa Formation	Toluviejo Formation	Chengue Fm.	Arroyo de Piedra Formation	?	?	
Paleocene			San Calletano Arroyo seco Formation	San Calletano Arroyo seco Formation	San Calletano Arroyo seco Formation	Arroyo seco Formation	Macarao Formation	Santa Rita Formation	Soebi Blanco Conglomerates
Cretaceous	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement		Cretaceous basement



Volcanic rocks



Continental/ Transitional siliciclastics

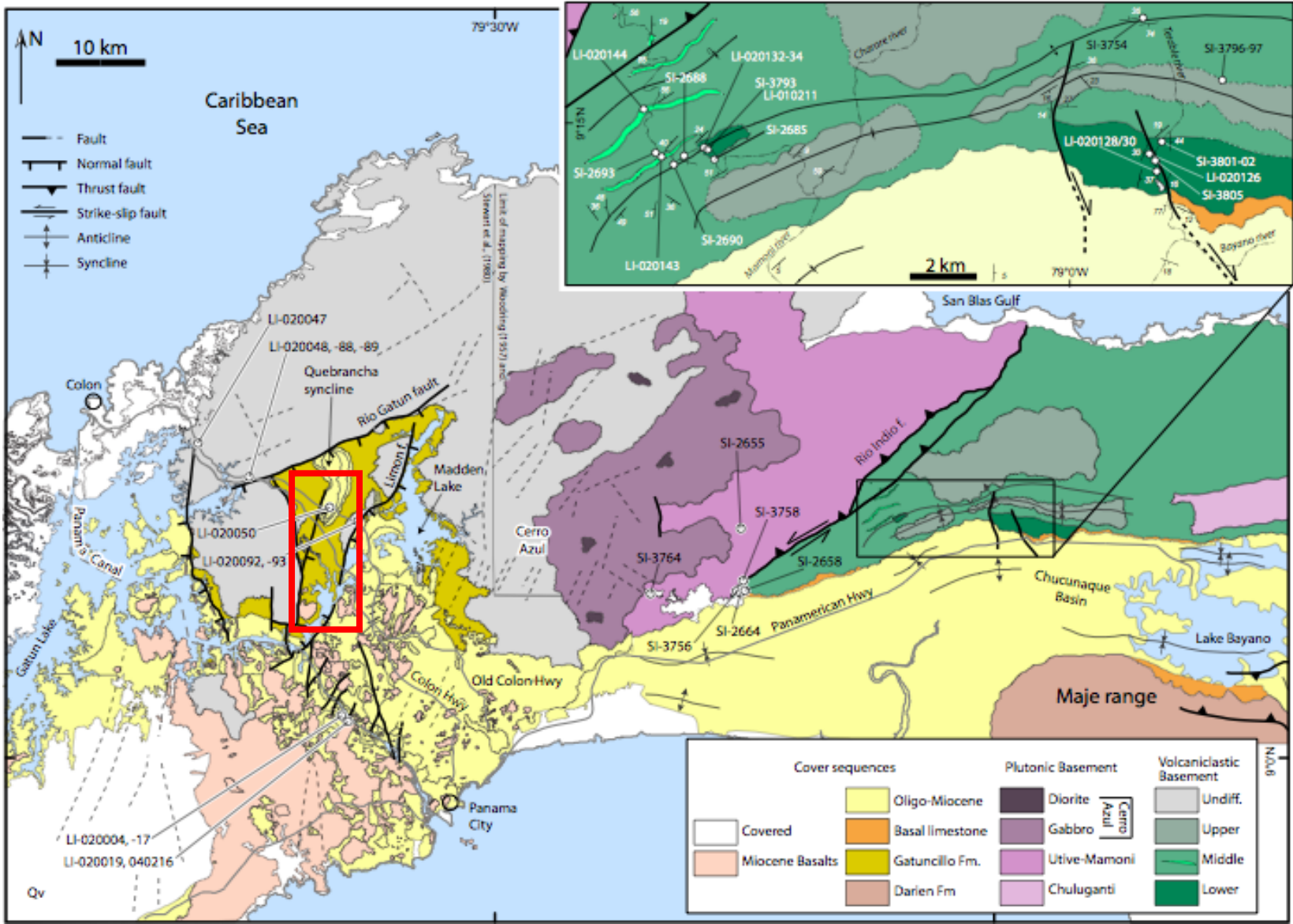


Carbonates

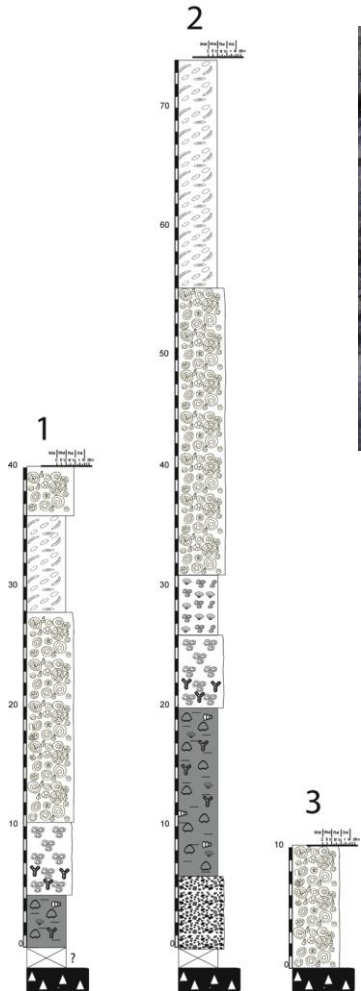


Deep marine siliciclastics

Panama



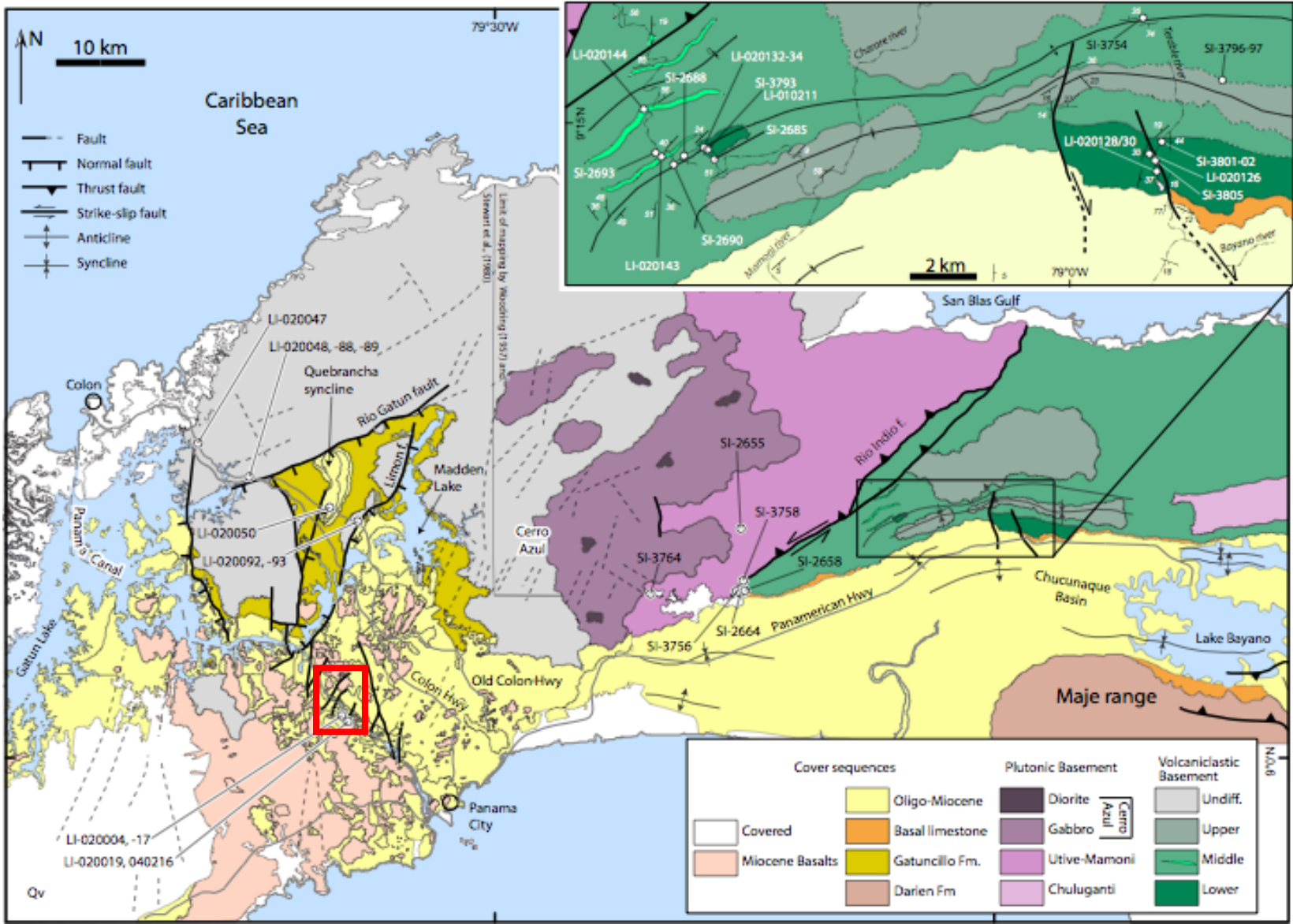
# Gatuncillo Formation



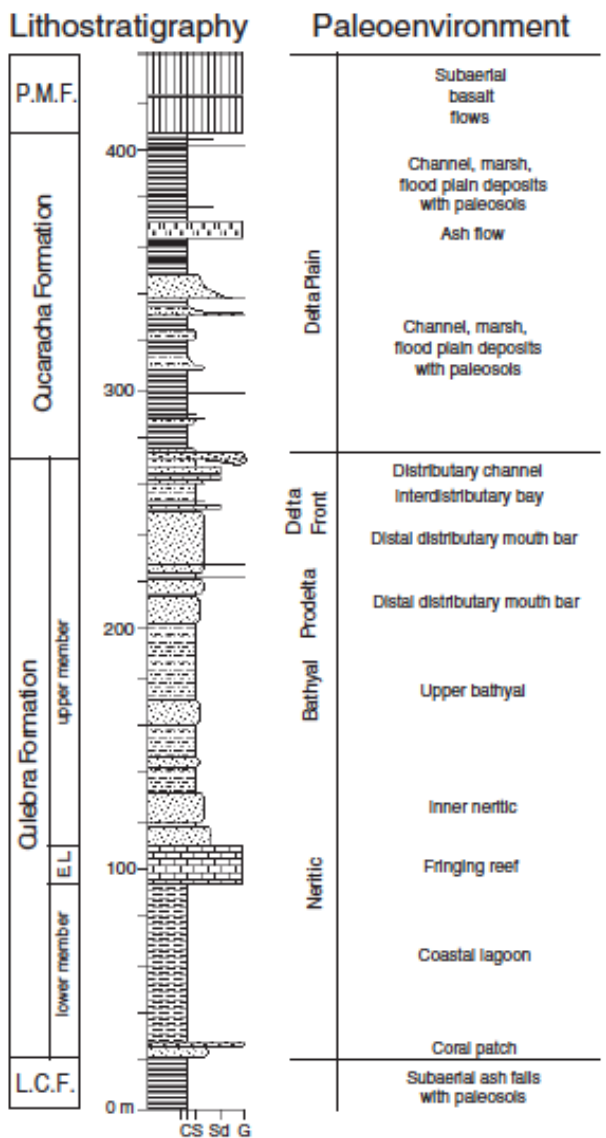
Shallow marine (Rhodagal/Foraminifera factory)



Panama

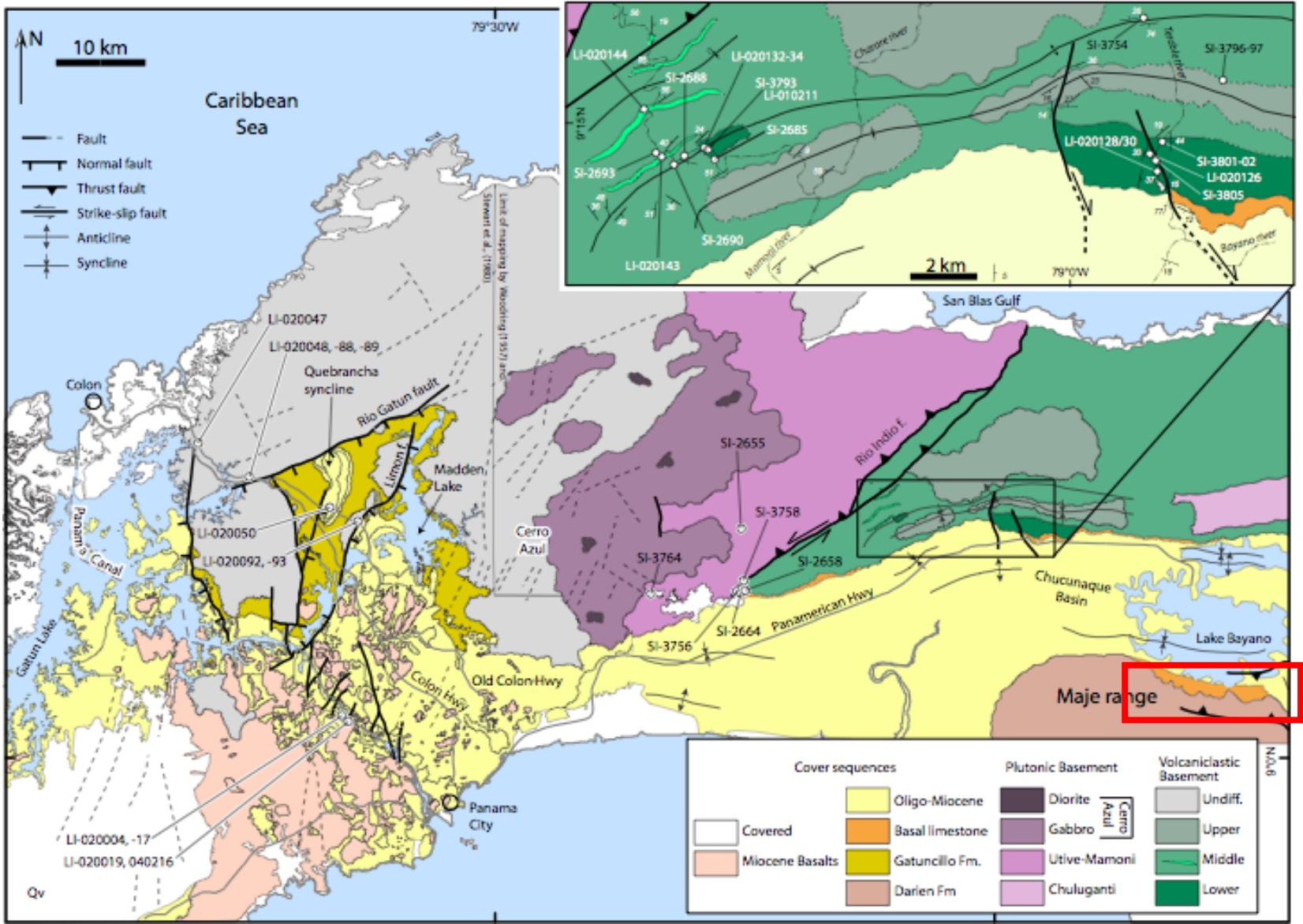


# Gatun Formation



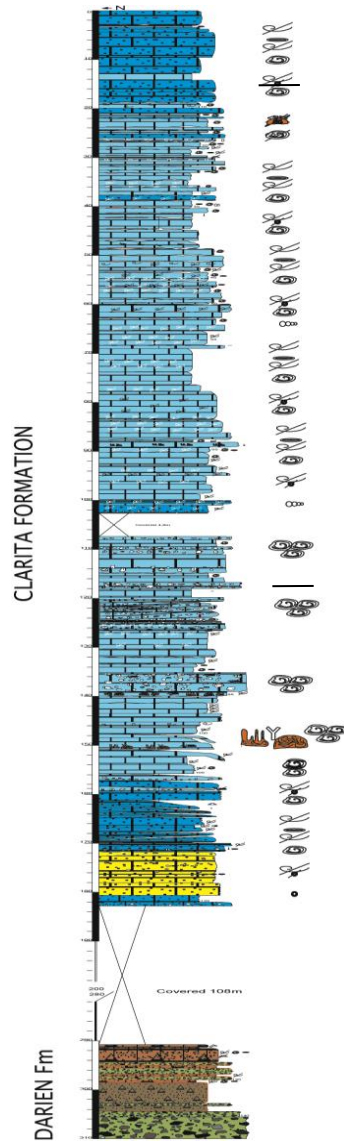
Shallow marine (Coral, mollusks factory)

Panama





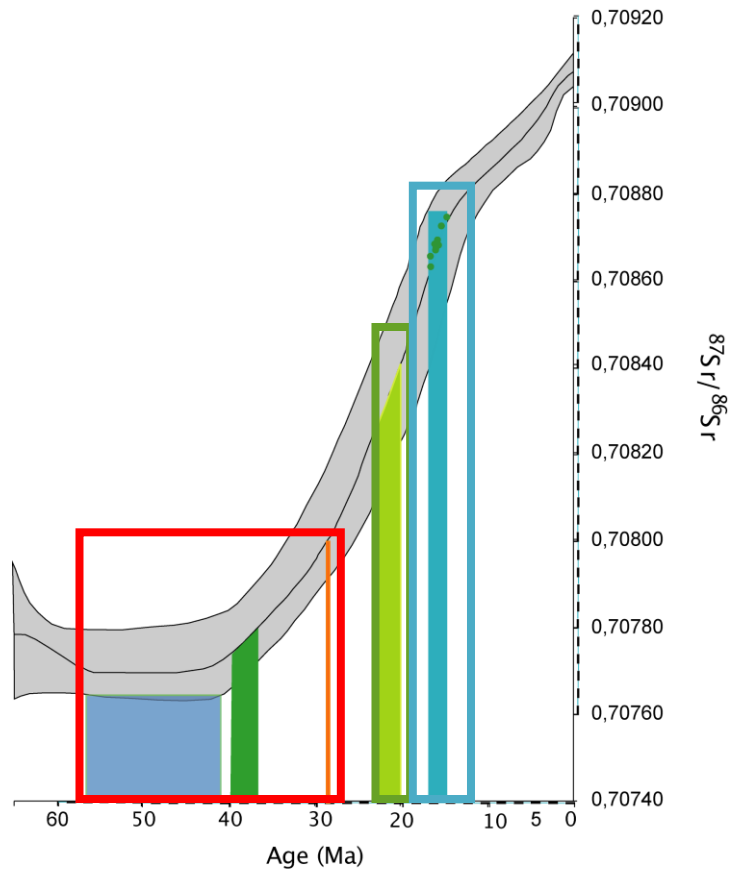
# Gatun Formation



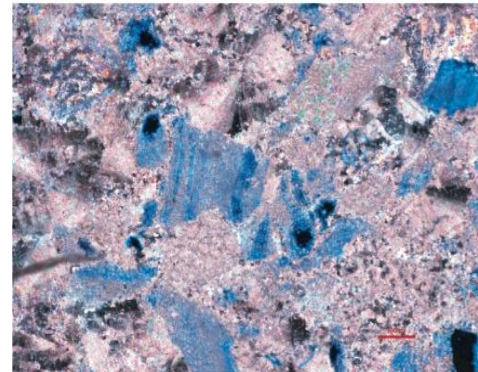
Shallow marine (Rhodalgal/Foraminifera factory)



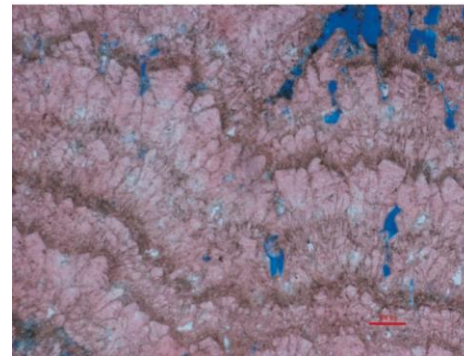
## Panama



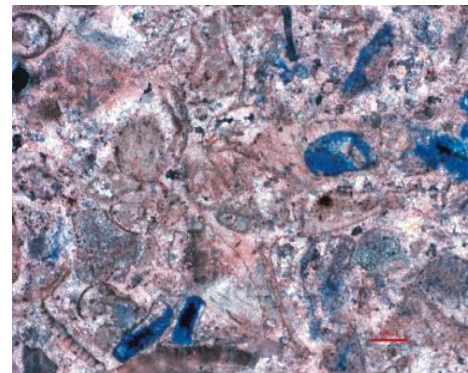
- Fm La Clarita
- Fms Boca, Culebra y Emperador (Kirby et al., 2008)
- Fm Gatuncillo (cantera cementos Cemex)
- Fm Gatuncillo (Autopista ciudad de Panama-Colon)
- Carbonatos via Santo Domingo



10-20% porosity



<1% porosity



4-10% porosity

# San Jacinto





# Lithostratigraphy of the SE Circum-Caribbean

Age	Panama Channel Kirby et al. (2008)	Chucunaque basin (This study)	San Jacinto Fold Belt South Guzman (2007)	San Jacinto Fold Belt Central Guzman (2007)	San Jacinto Fold Belt, Central U. Caldas- ANH (2009)	Luruaco anticlinorium Guzman (2007)	Baja Guajira Lockwood (1966)	Falcon/Urumaco Quiroz et al. (2012)	Bonaire Herweijer et al. (1977)
Pleistocene	Bocas Formation					La Popa Formation			Seroi Dome Formation
Pliocene			Sincelejo Formation	Sincelejo Formation	Sincelejo Formation	Rotinet Formation			
							Castilletes Formation	Urumaco Formation	
Miocene			Cerrito Formation	Cerrito Formation	Cerrito Formation	Perdices-Tubara Formations			
	Cucaracha Formation	Maje Formation	Porquero Formation	Porquero Formation	Porquero Formation	Ibacho Formation	Jimol Formation	Socorro Formation	
	Culebra Formation		Cienaga de Oro Formation	Porquero Formation	Cienaga de Oro Formation	Arjona Formation	Jimol/ Formation	Uitpa Fm.	Agua Clara Formation
Oligocene	Las Cascadas Formation	Darien Formation		Cienaga de Oro Formation	Chengue Fm.	Carmen Formation	Siamana Formation	Pecaya Fm.	San Luis Formation
				Chengue Fm.	Toluviejo Formation		?	?	
Eocene	Gatuncillo Formation		Tampa Formation	Toluviejo Formation	San Calletano Arroyo seco Formation	Arroyo de Piedra Formation			Soebi Blanco Conglomerates
Paleocene			San Calletano Arroyo seco Formation	San Calletano Arroyo seco Formation		Arroyo seco Formation	Macarao Formation	Santa Rita Formation	
Cretaceous	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement		Cretaceous basement

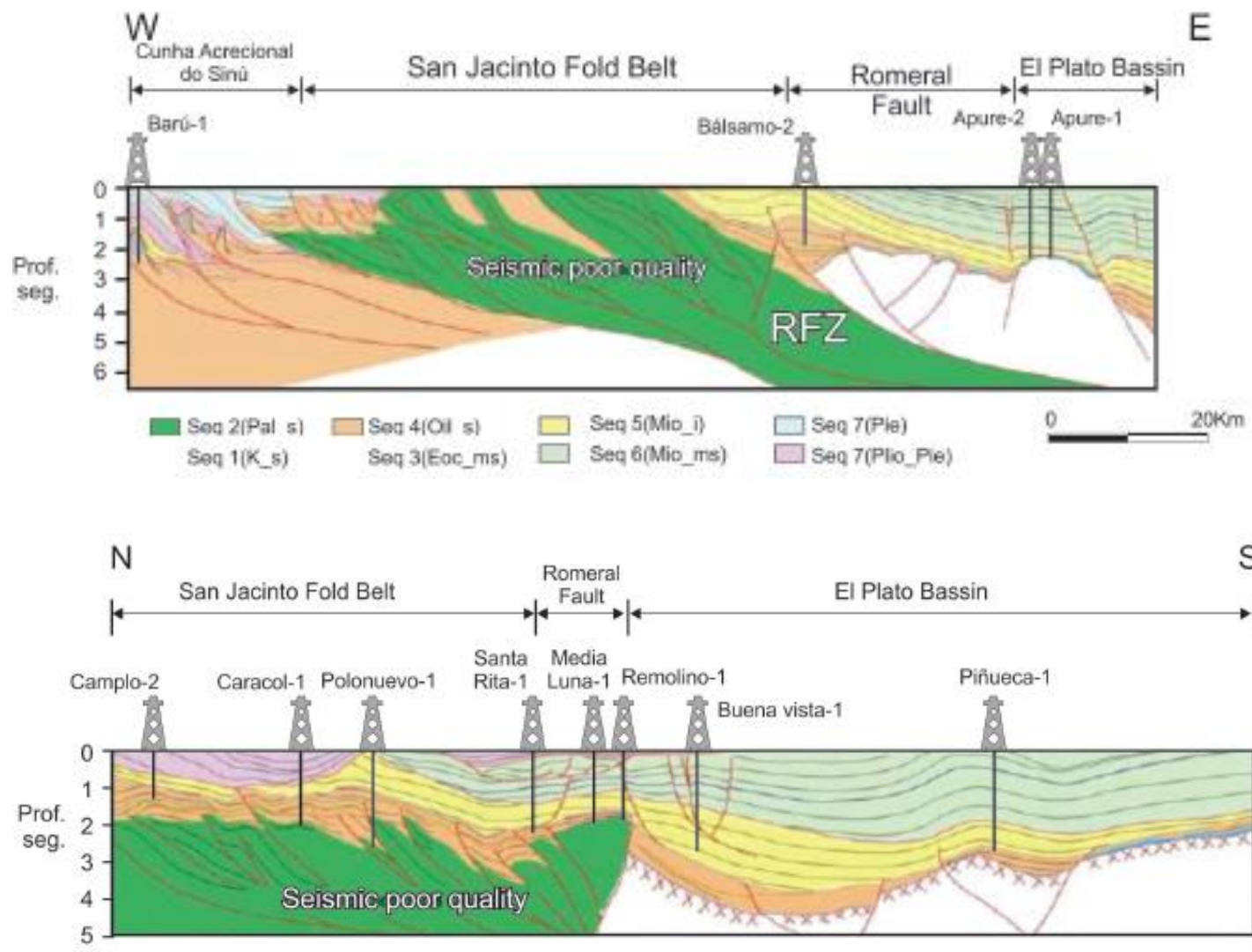
Volcanic rocks

Continental/ Transitional siliciclastics

Carbonates

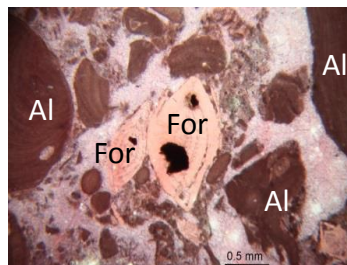
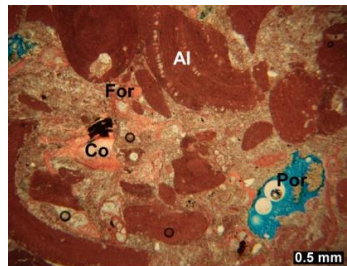
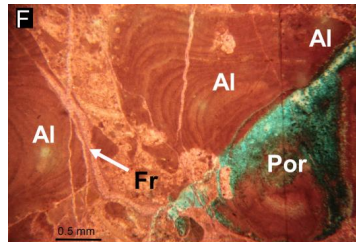
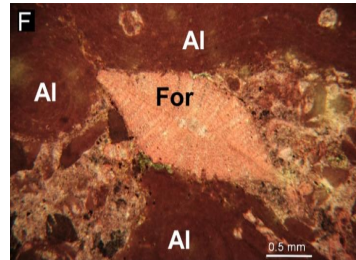
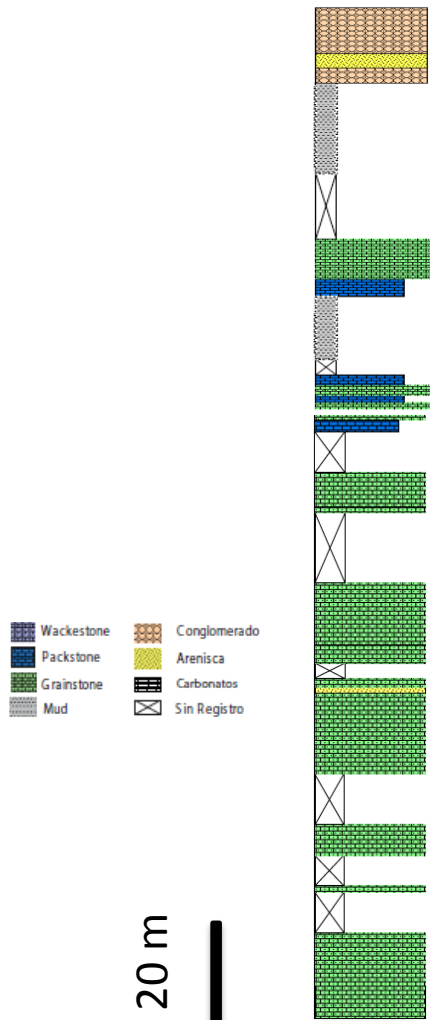
Deep marine siliciclastics

# San Jacinto



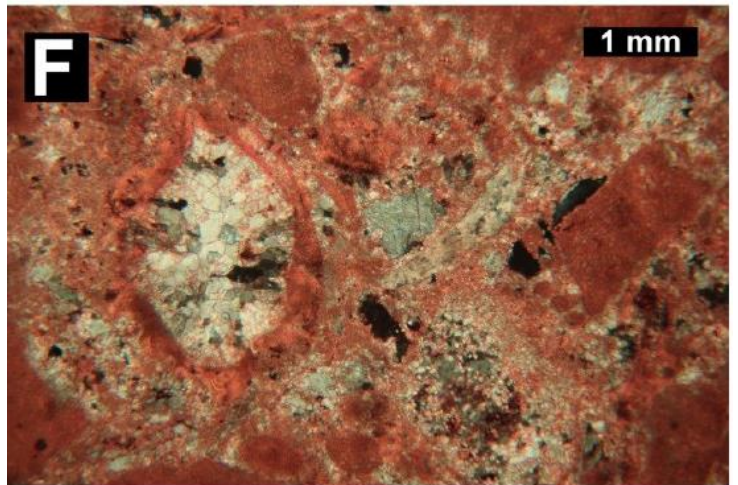
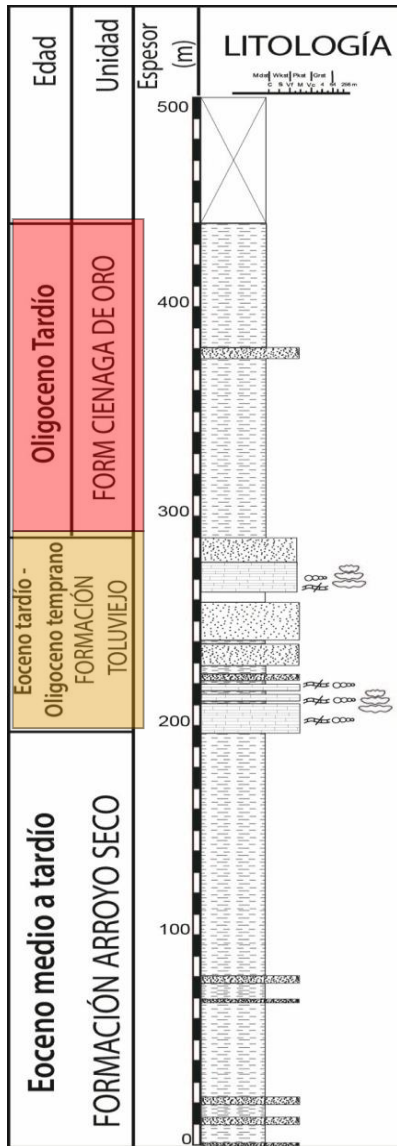


## San Jacinto



**Shallow marine  
(Rhodagal/Foraminifera factory)  
Porosities <4%**

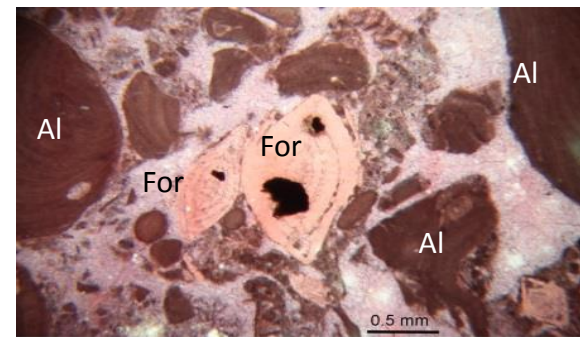
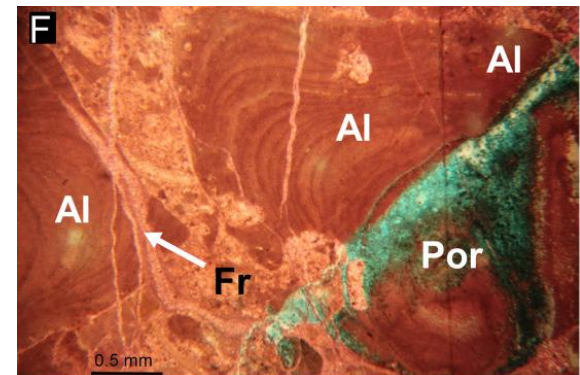
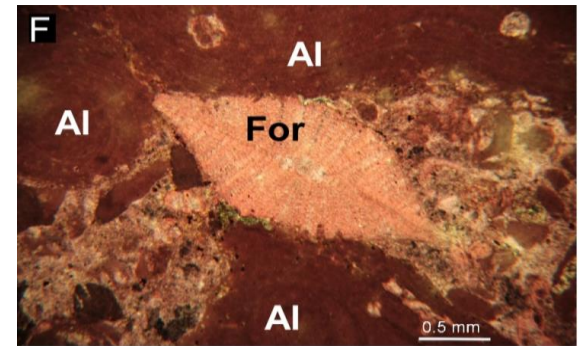
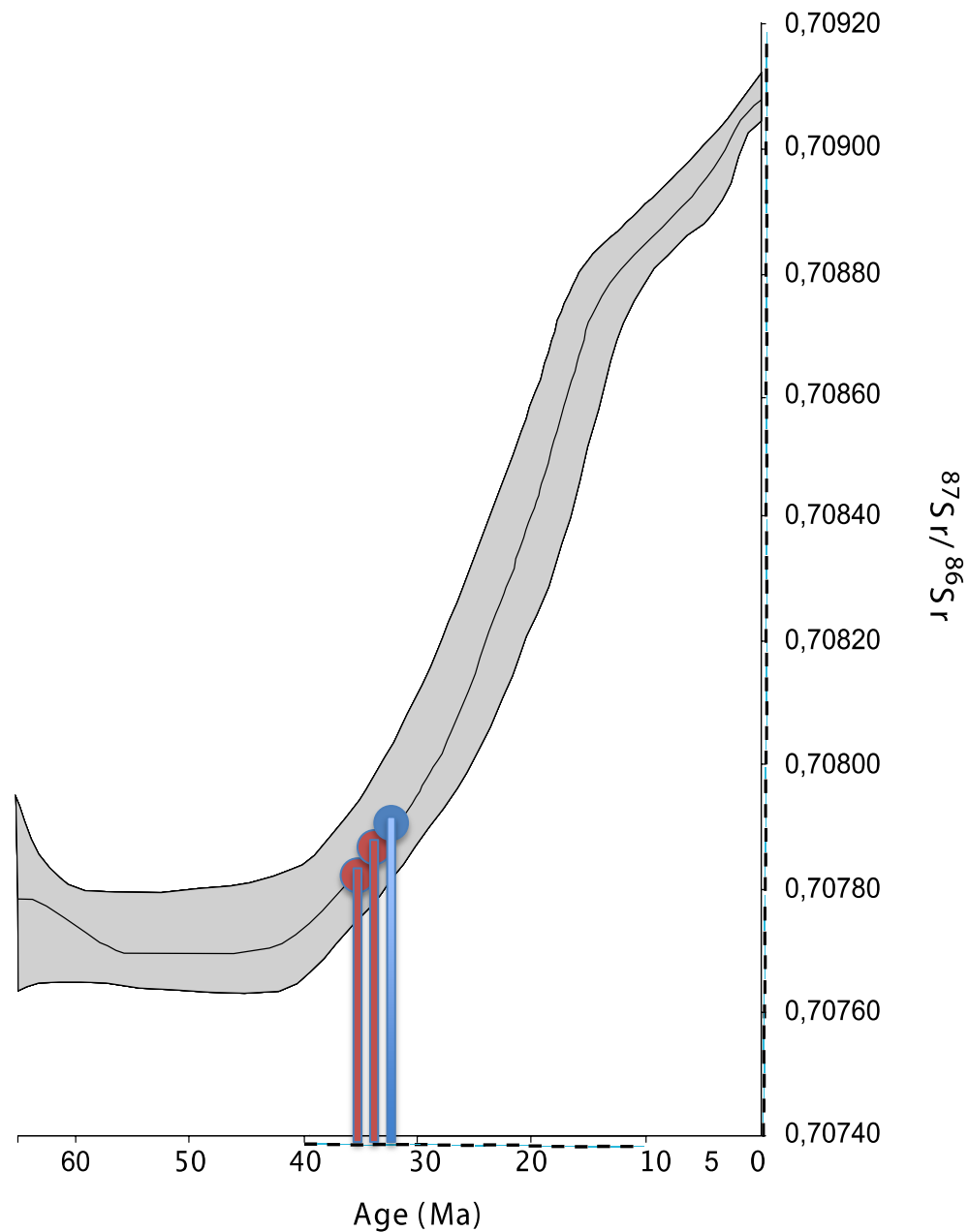
# San Jacinto



**Shallow marine  
(Rhodalgal/Foraminifera factory)**



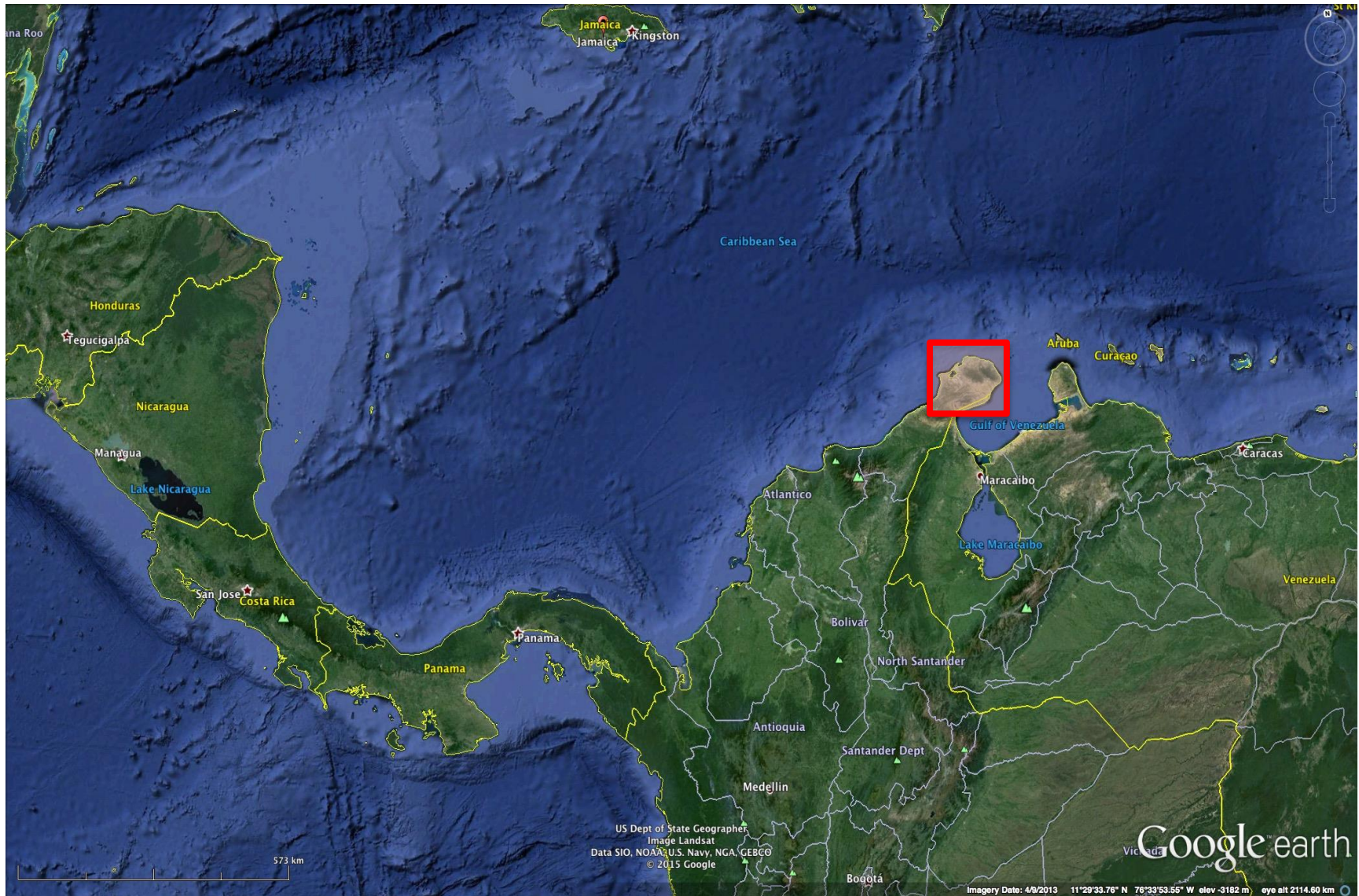
# Stratigraphic Records



**Shallow marine  
(Rhodalgal/Foraminifera factory)**



# Cosinetas basin



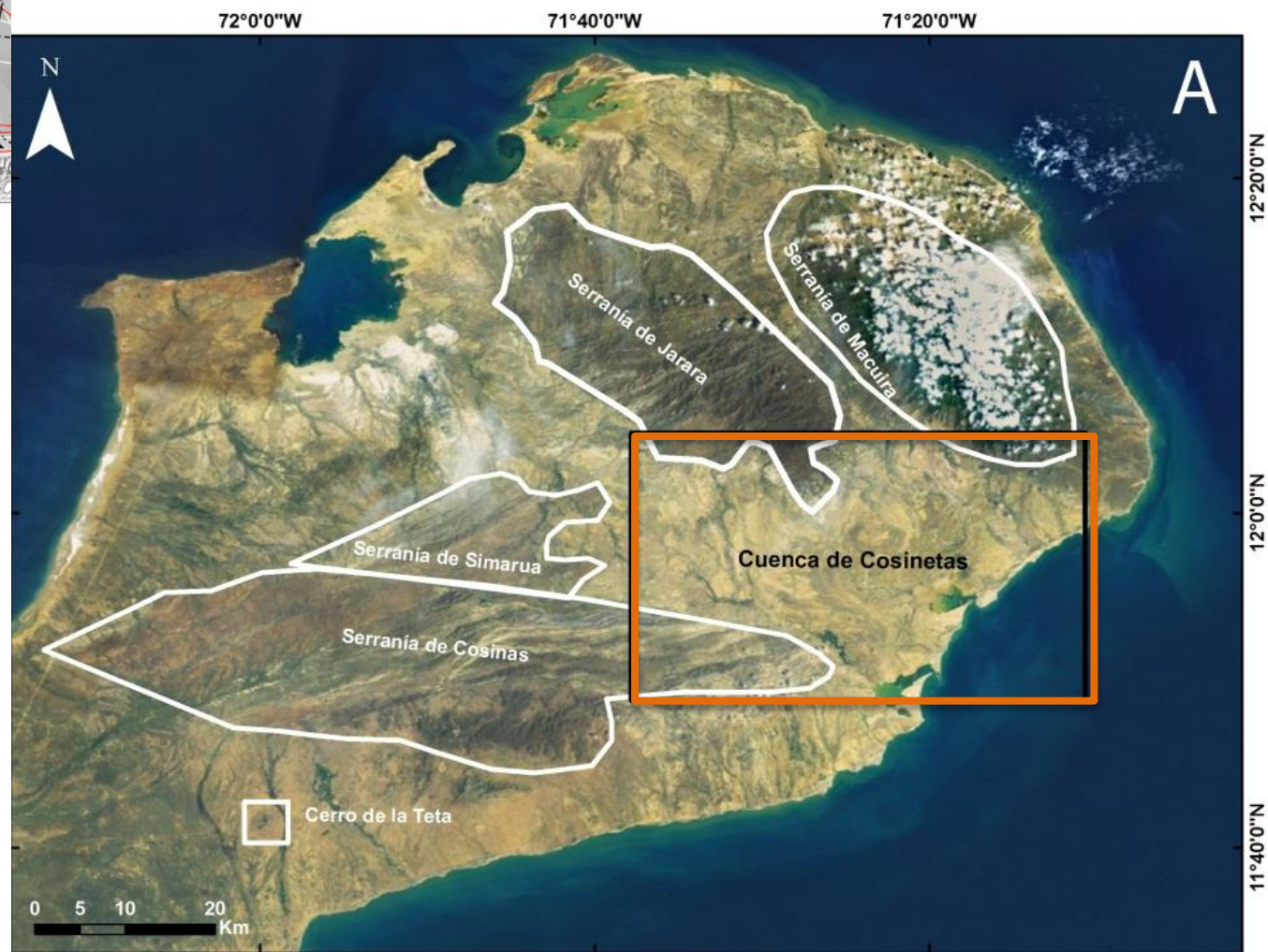
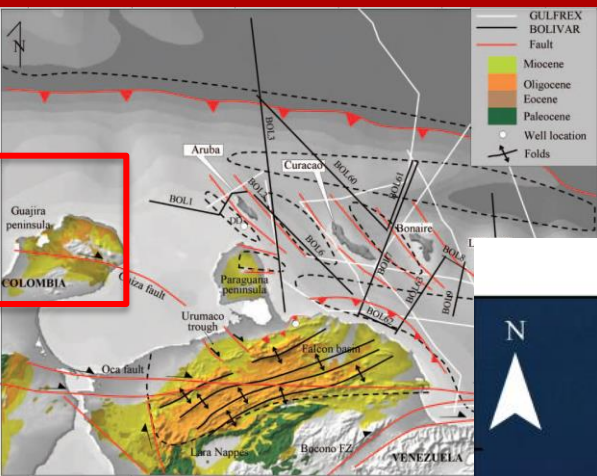
Lithostratigraphy of the SE Circum-Caribbean

Age	Panama Channel Kirby et al. (2008)	Chucunaque basin (This study)	San Jacinto Fold Belt South Guzman (2007)	San Jacinto Fold Belt Central Guzman (2007)	San Jacinto Fold Belt, Central U. Caldas- ANH (2009)	Luruaco anticlinorium Guzman (2007)	Baja Guajira Lockwood (1966)	Falcon/Urumaco Quiroz et al. (2012)	Bonaire Herweijer et al. (1977)
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	Culebra Formation		Cienaga de Oro Formation	Porquero Formation	Cienaga de Oro Formation	Arjona Formation	Jimol/ Formation	Agua Clara Formation	
Oligocene	Las Cascadas Formation	Darien Formation		Cienaga de Oro Formation	Chengue Fm.	Carmen Formation	Uitpa Fm.	Pecaya Fm.	San Luis Formation
					Toluviejo Formation		Siamana Formation		
Eocene	Gatuncillo Formation		Tampa Formation	Toluviejo Formation	San Calletano Arroyo seco Formation	Arroyo de Piedra Formation	?	?	
				Chengue Fm.			Macarao Formation	Santa Rita Formation	Soebi Blanco Conglomerates
Paleocene			San Calletano Arroyo seco Formation	San Calletano Arroyo seco Formation		Arroyo seco Formation			
Cretaceous	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement	Cretaceous basement		Cretaceous basement

Volcanic rocks      Continental/ Transitional siliciclastics      Carbonates      Deep marine siliciclastics



# Cosinetas basin

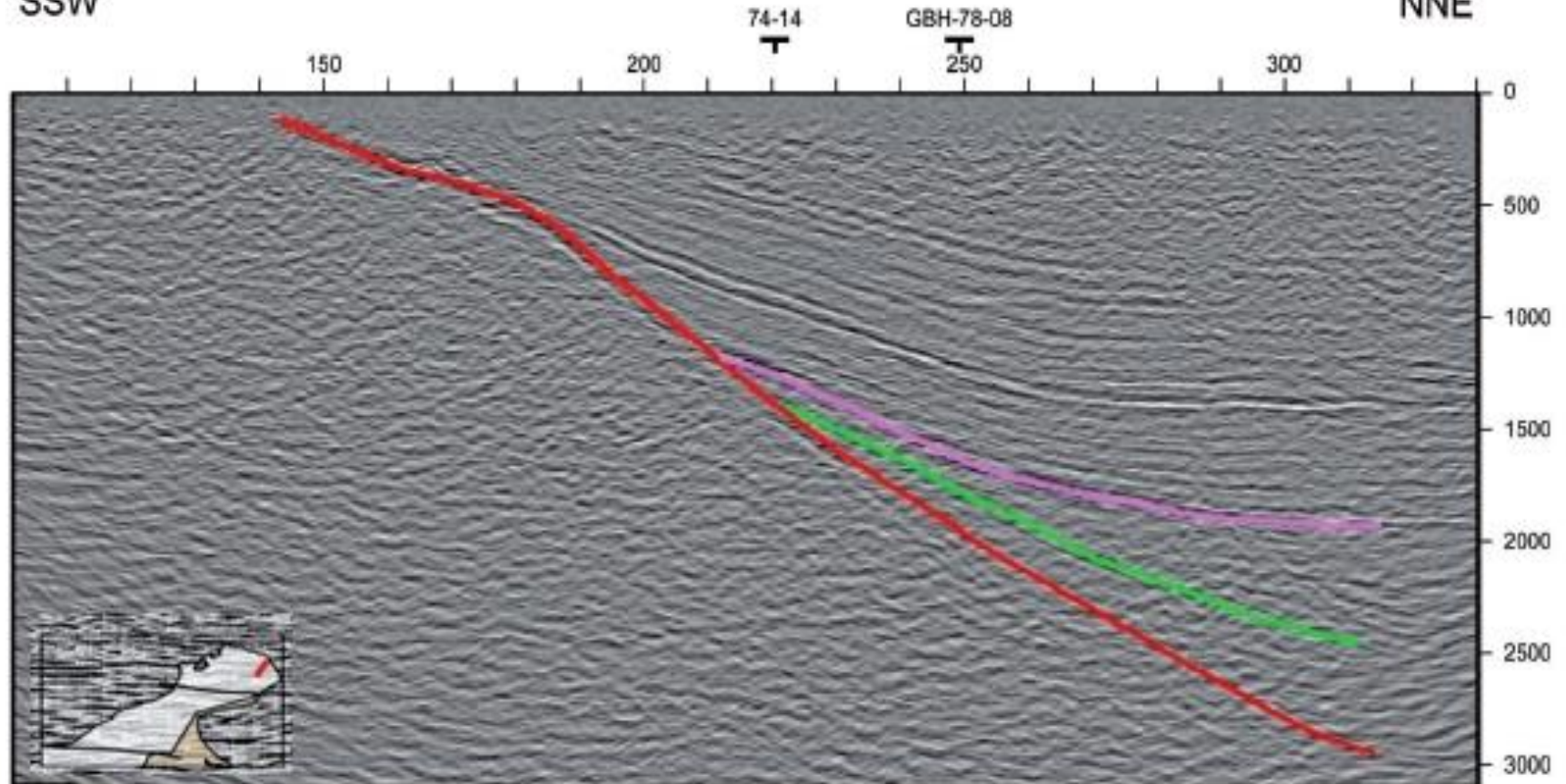




# Cosinetas basin

Line 74-06  
SSW

NNE



mio08 RE92

16 in/cm 2.0 IPS

1034m

- Siamana Formation
- Macaraao Formation
- Top Basement



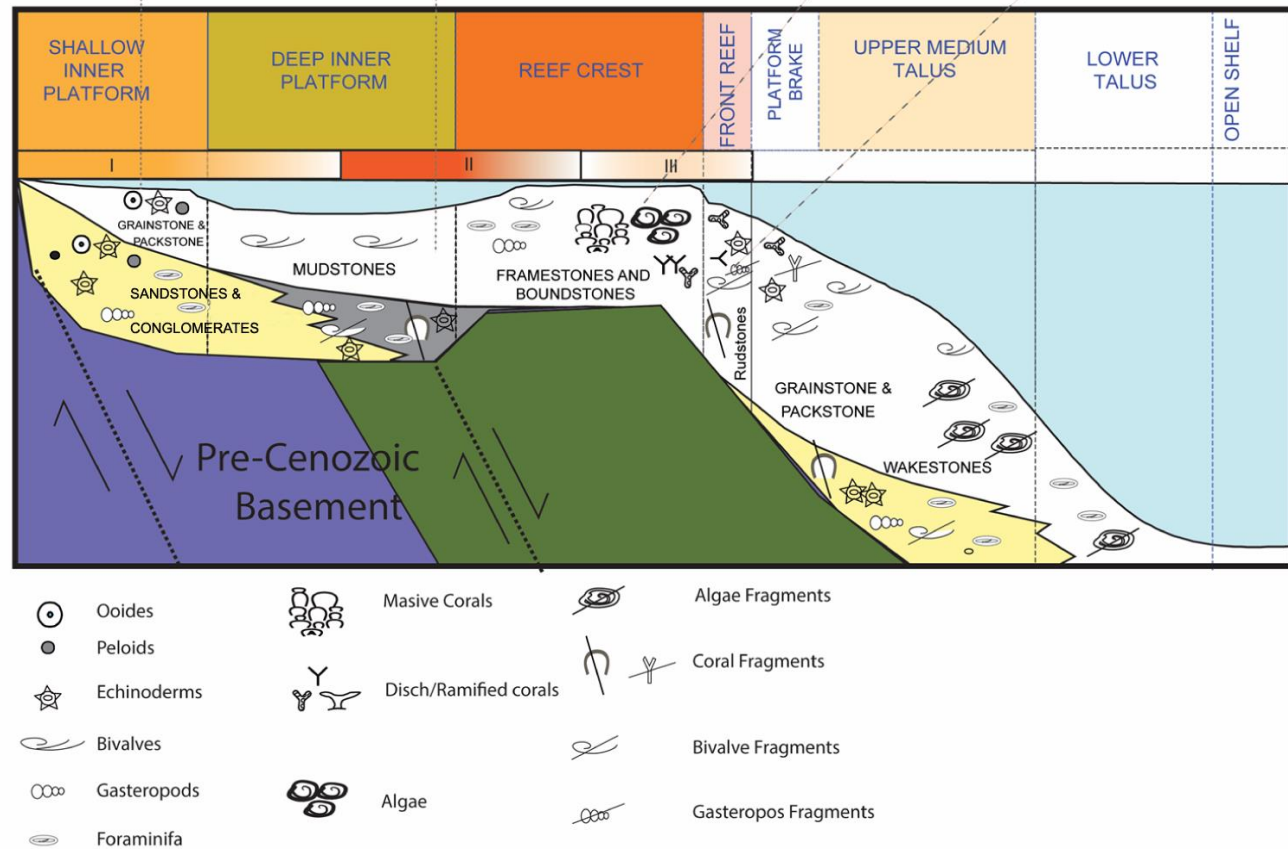
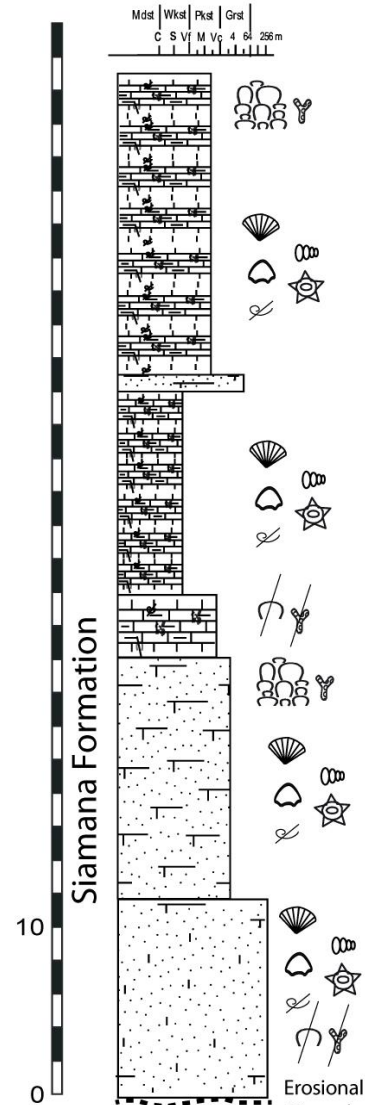
Serranía de Jarara

Formación Siamana

Neiss de Alas

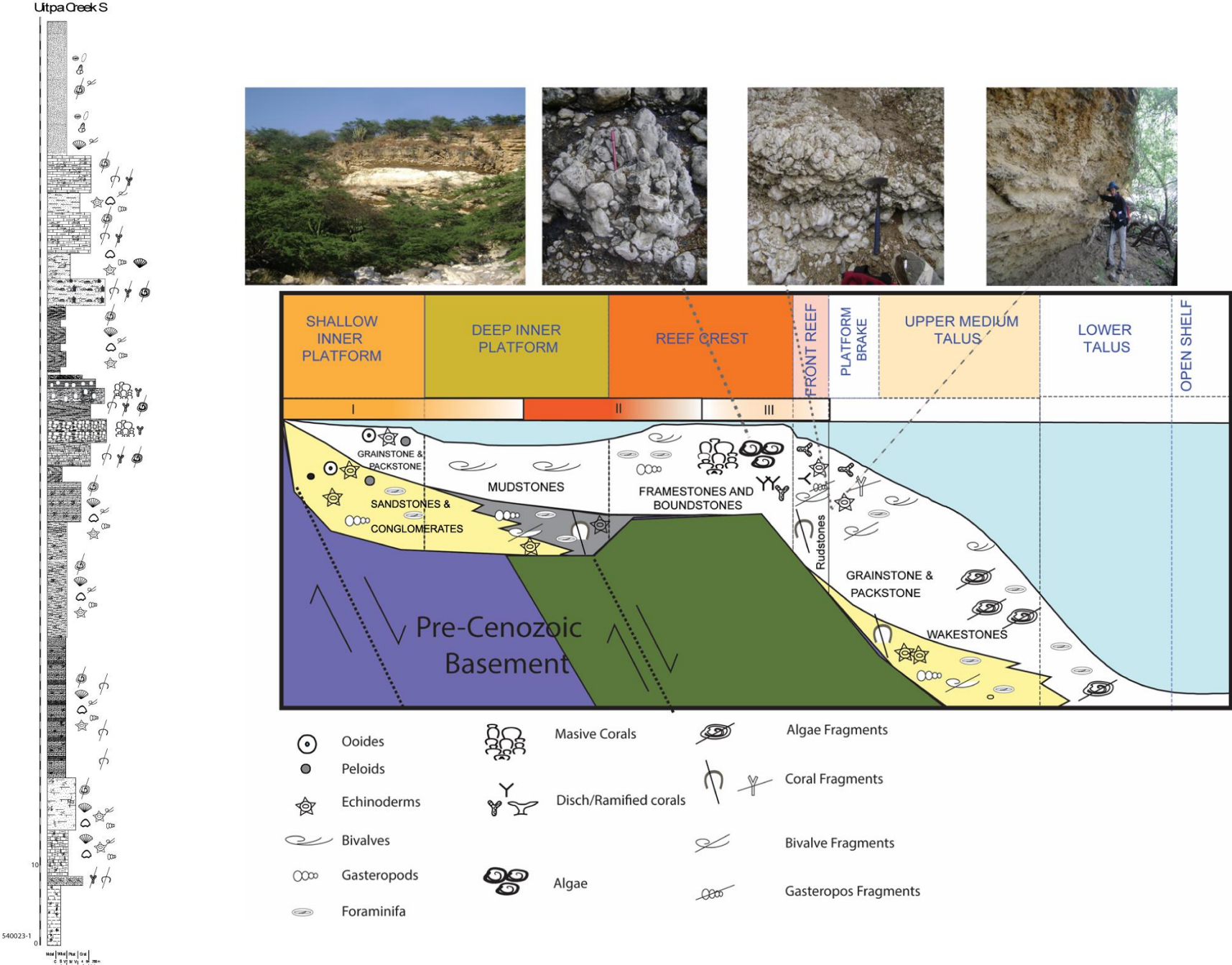


## Flor de la Guajira

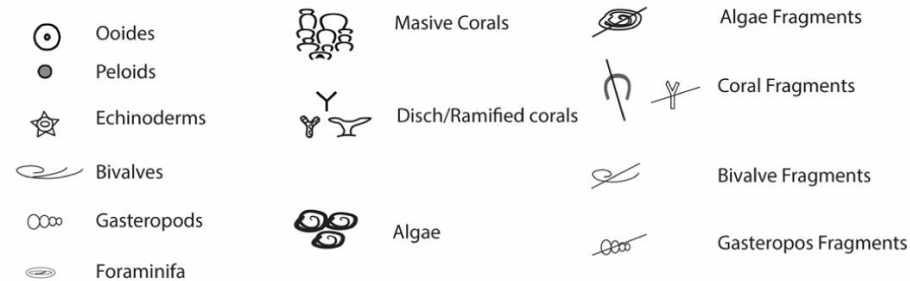
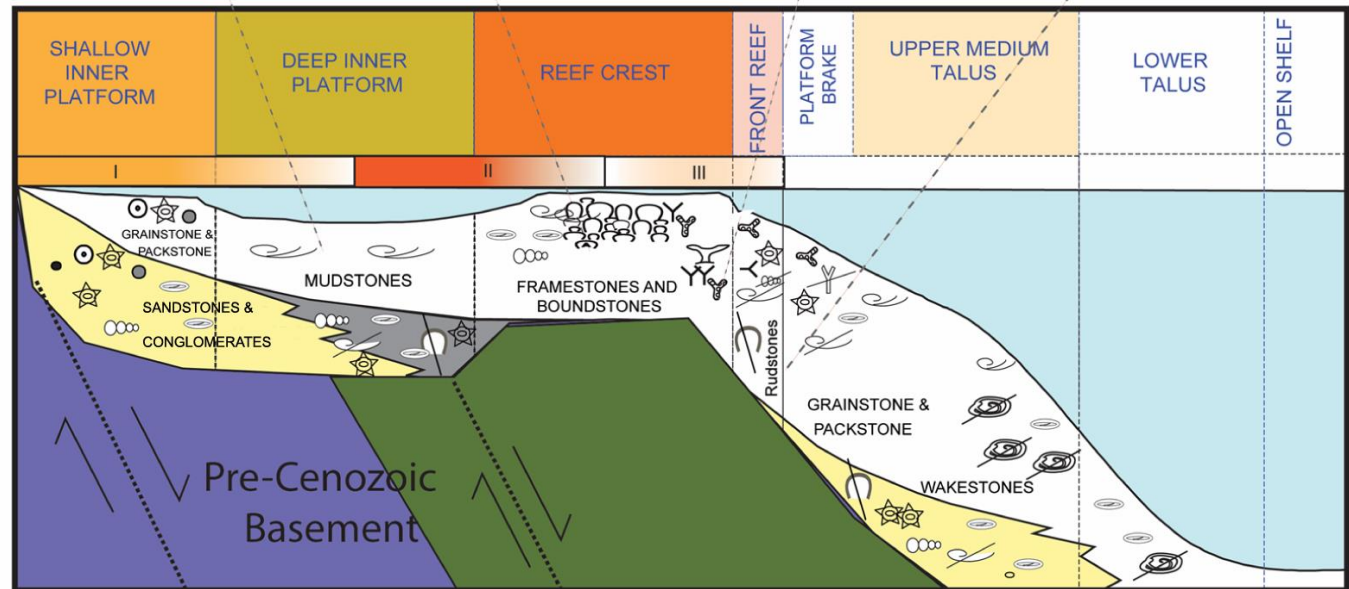
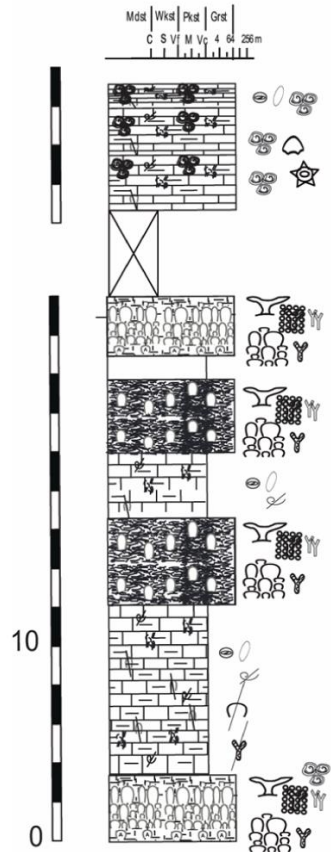




# Stratigraphic Records

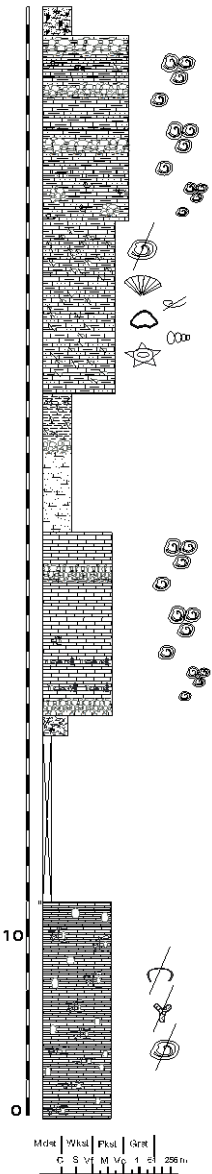
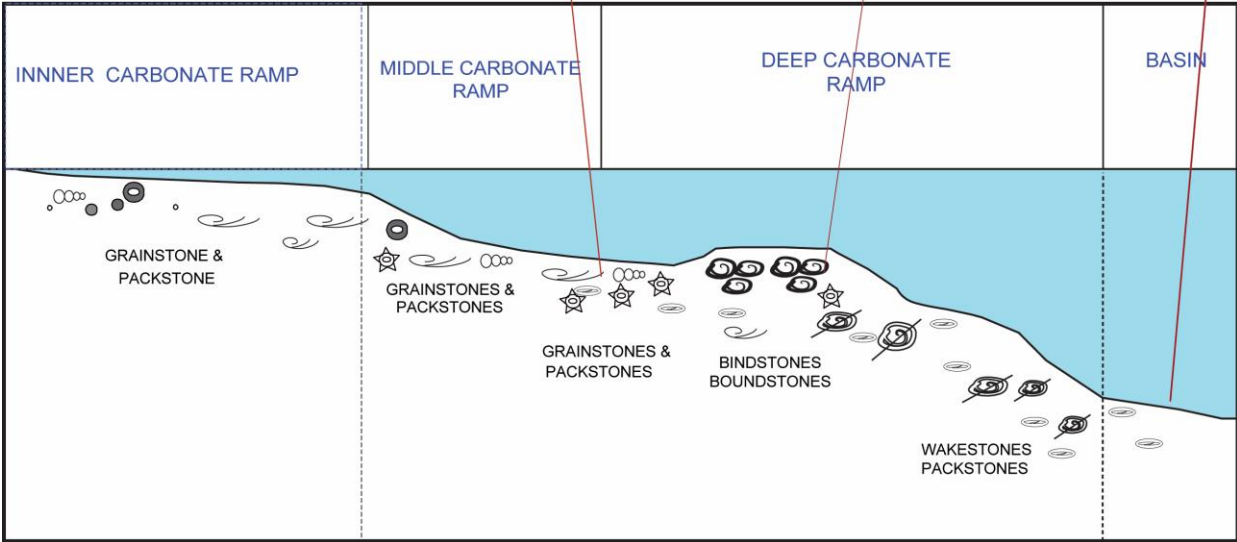
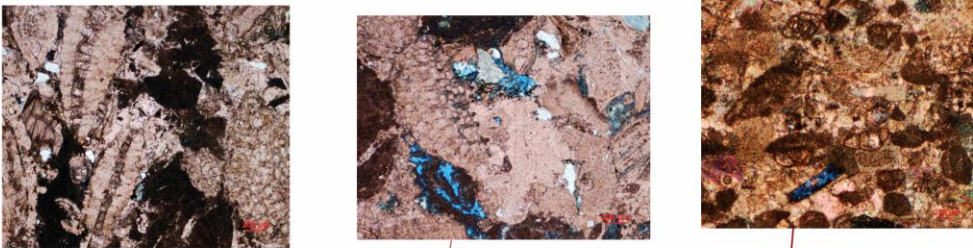


## Ekyeps Creek



Ekyeps N

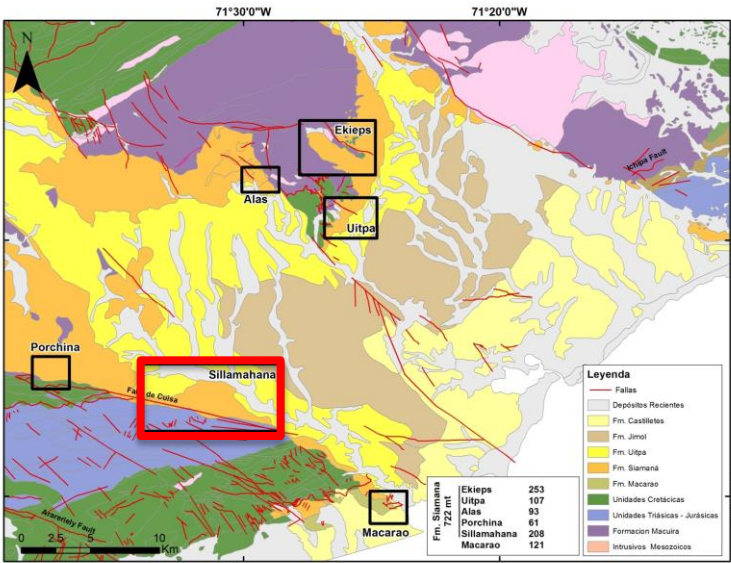
Primary dolomites associated with foraminifera and algae allochems



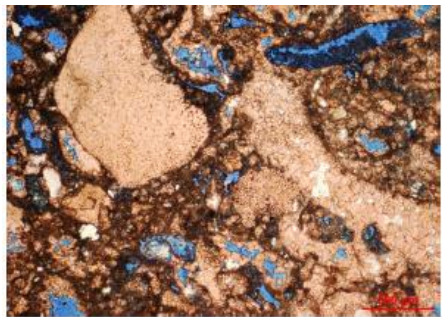
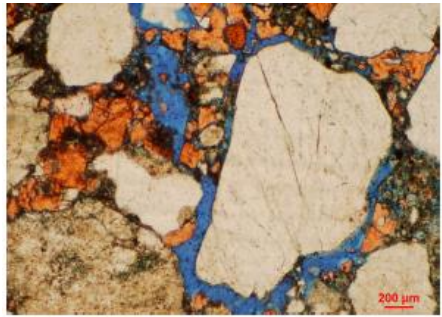
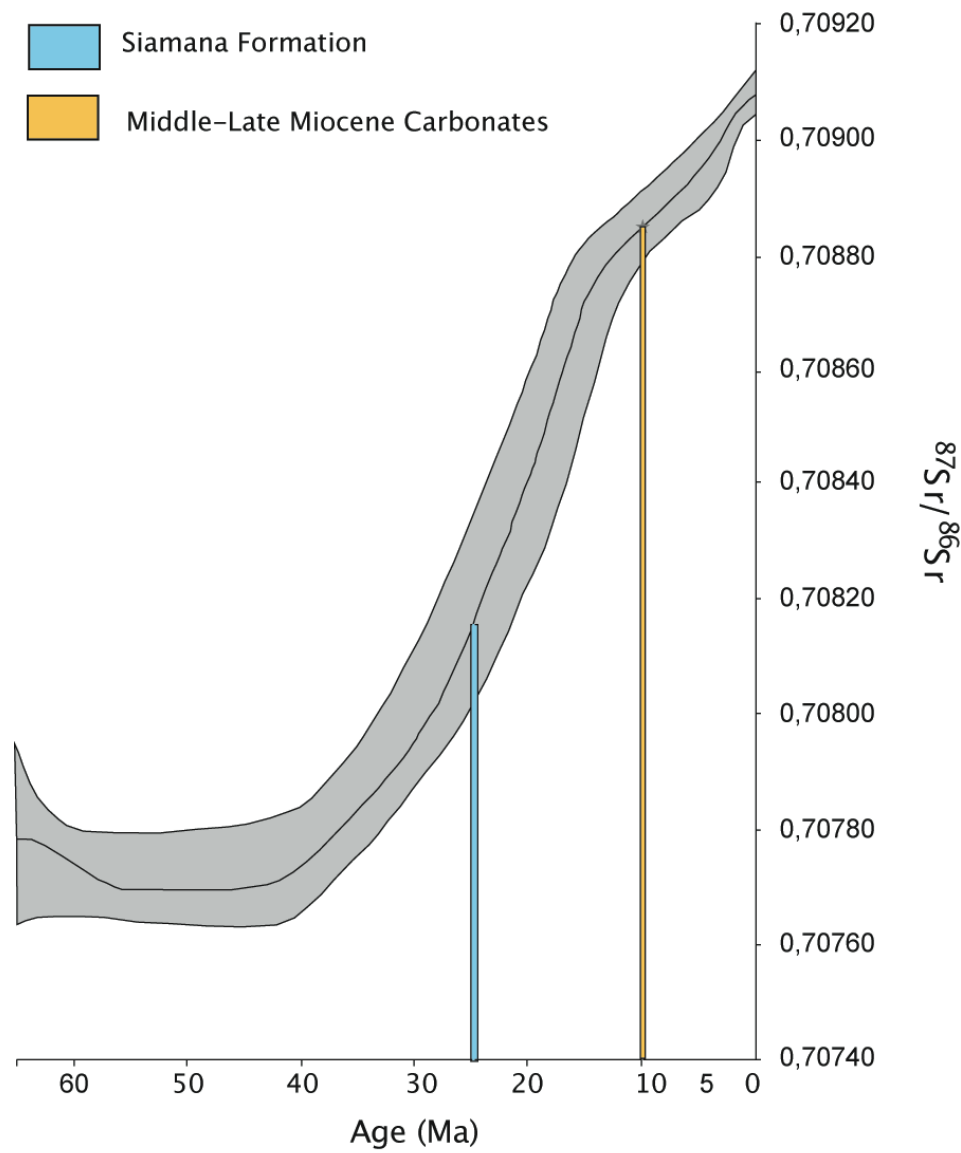
- |              |                       |                      |
|--------------|-----------------------|----------------------|
| Ooides       | Massive Corals        | Algae Fragments      |
| Peloids      | Disch/Ramified corals | Coral Fragments      |
| Echinoderms  | Bivalves              | Bivalve Fragments    |
| Gastropods   | Algae                 | Gastropods Fragments |
| Foraminifera |                       |                      |



# Stratigraphic Records



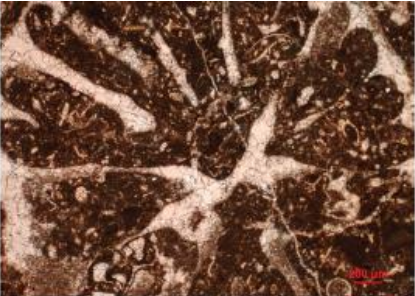
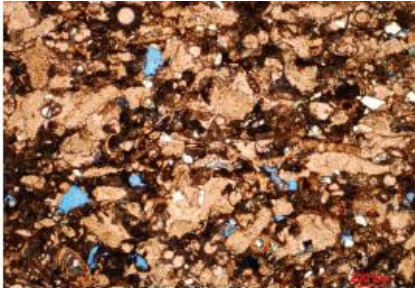
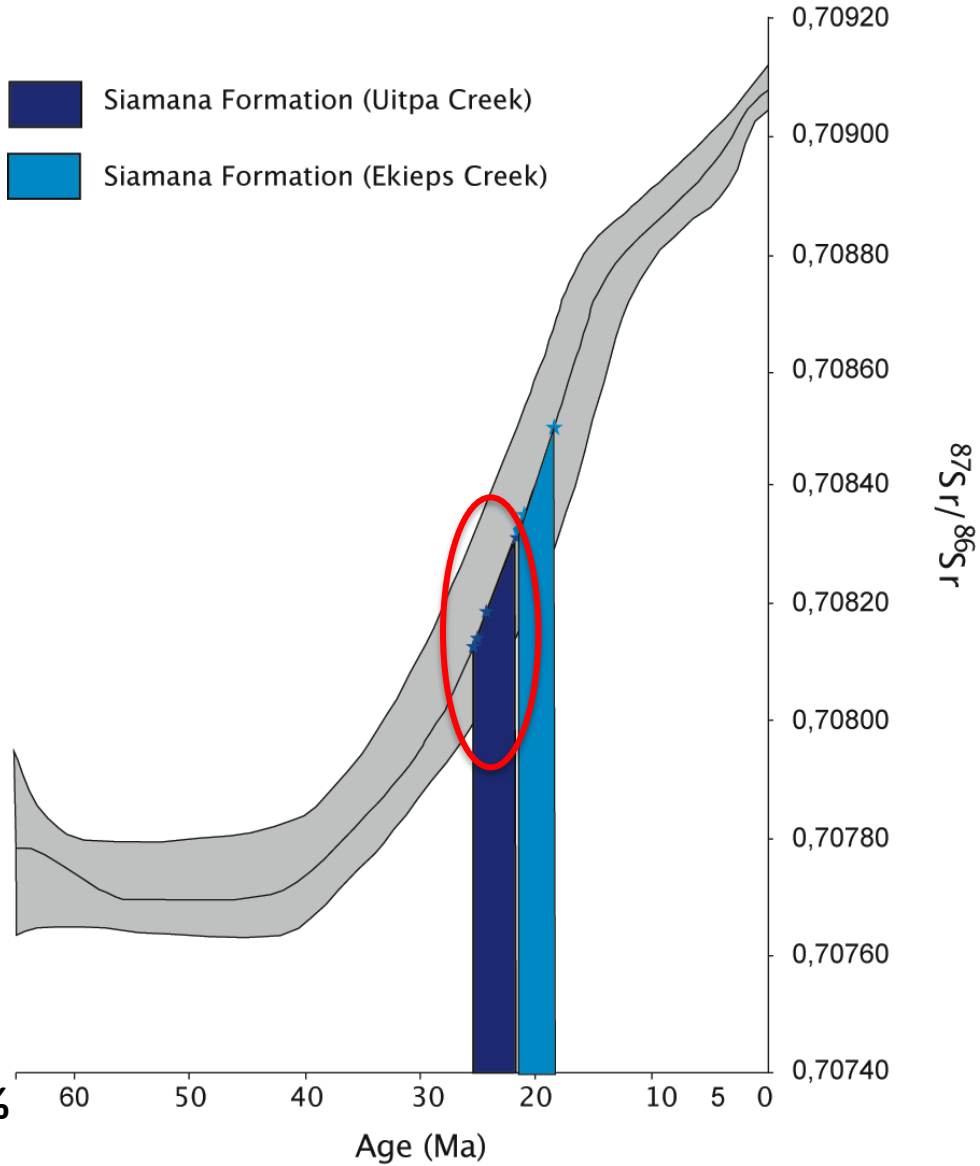
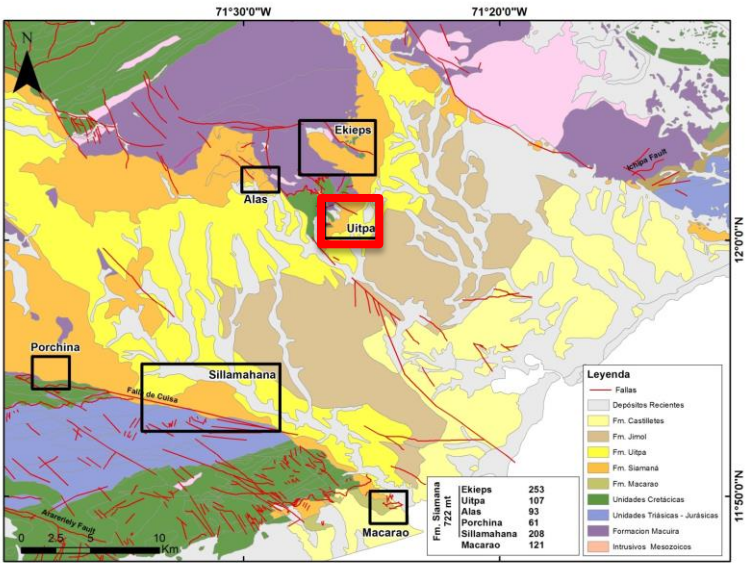
- Siamana Formation
- Middle-Late Miocene Carbonates



Porosities <4%

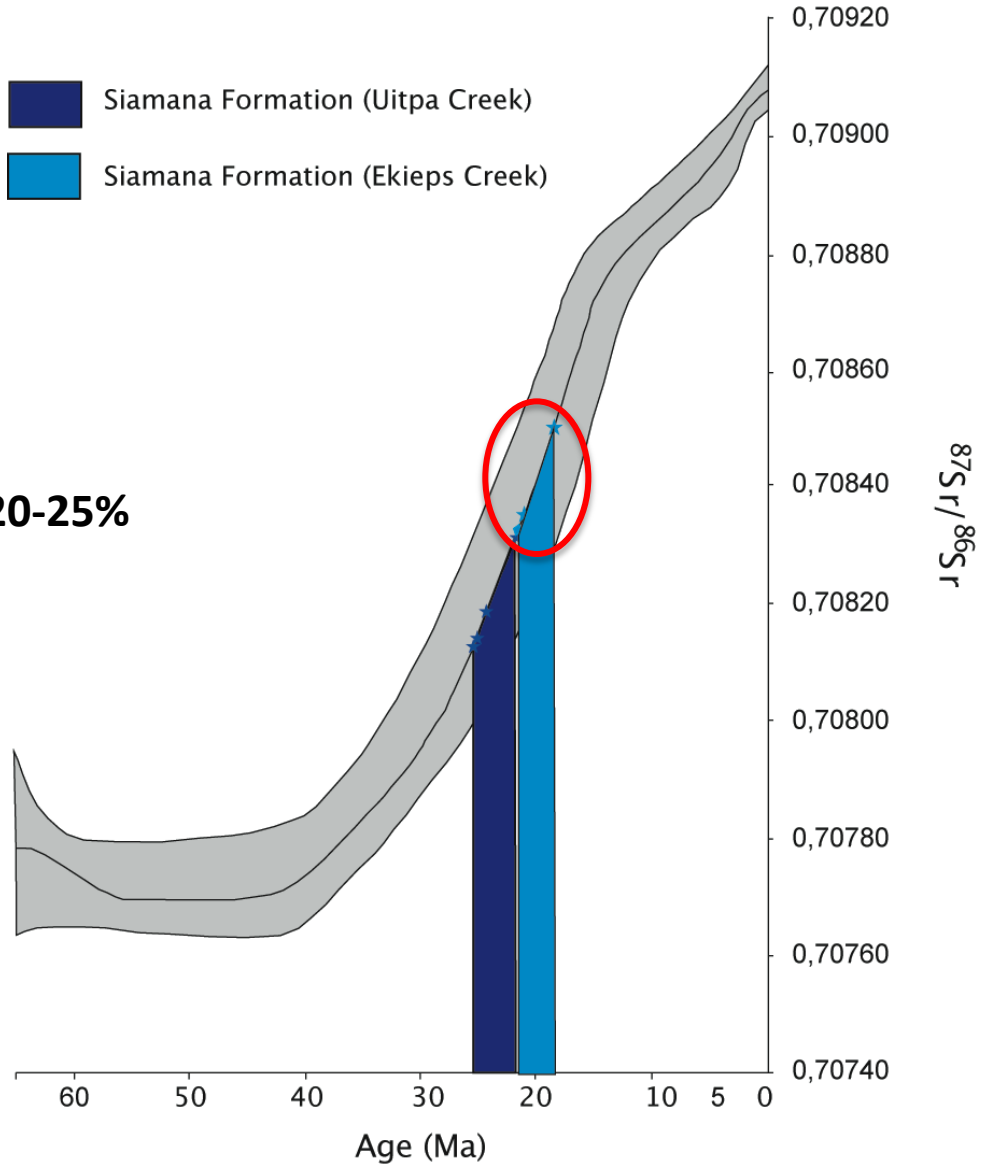
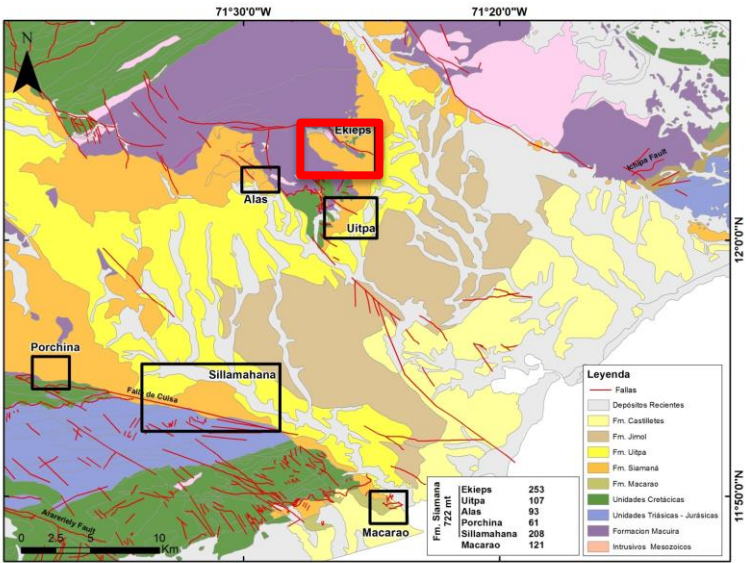
Porosities 10%  
dolomitization

# Stratigraphic Records

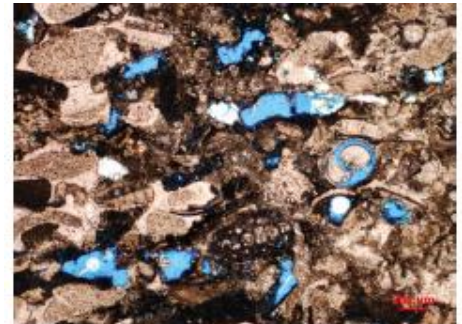
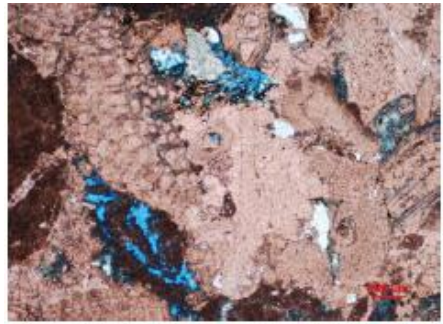


Porosities <4%

# Stratigraphic Records

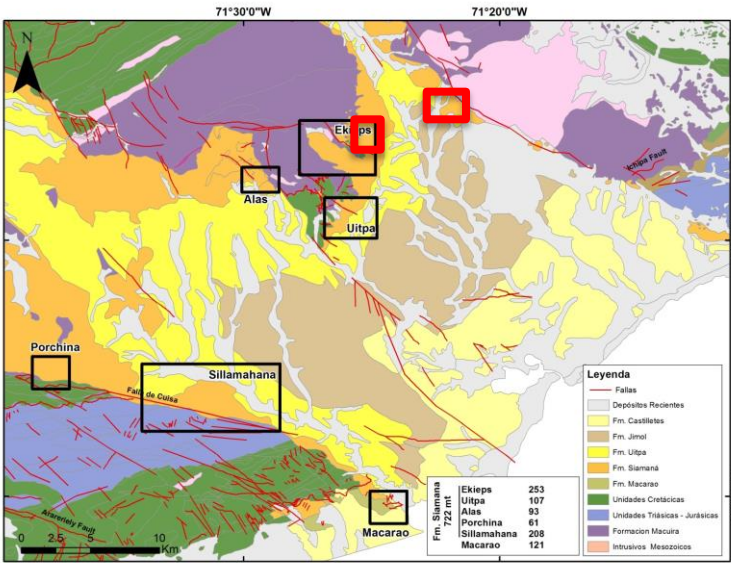


**Porosities 20-25%**

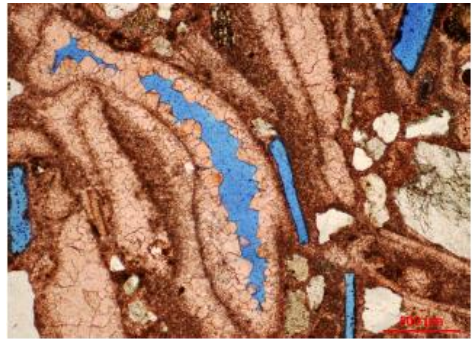




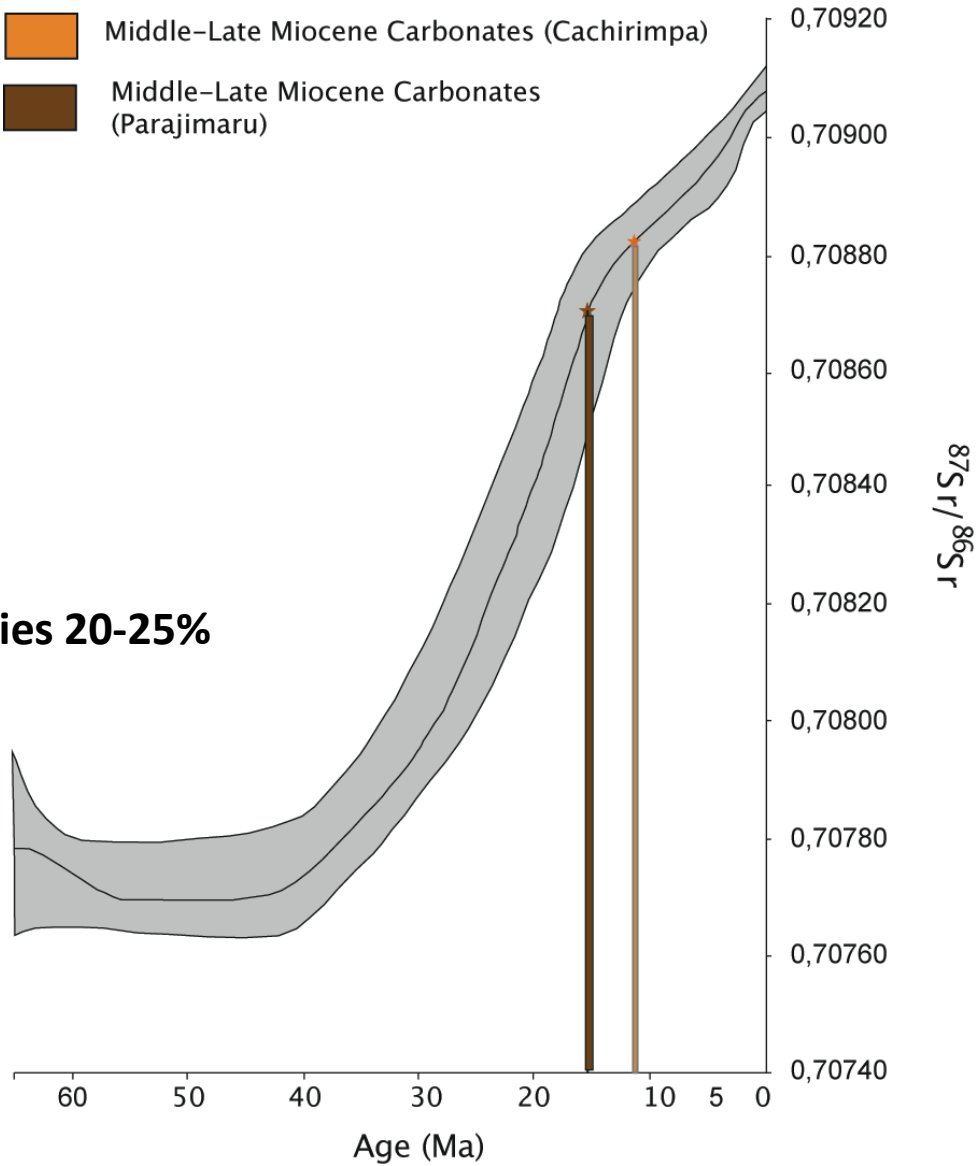
# Stratigraphic Records



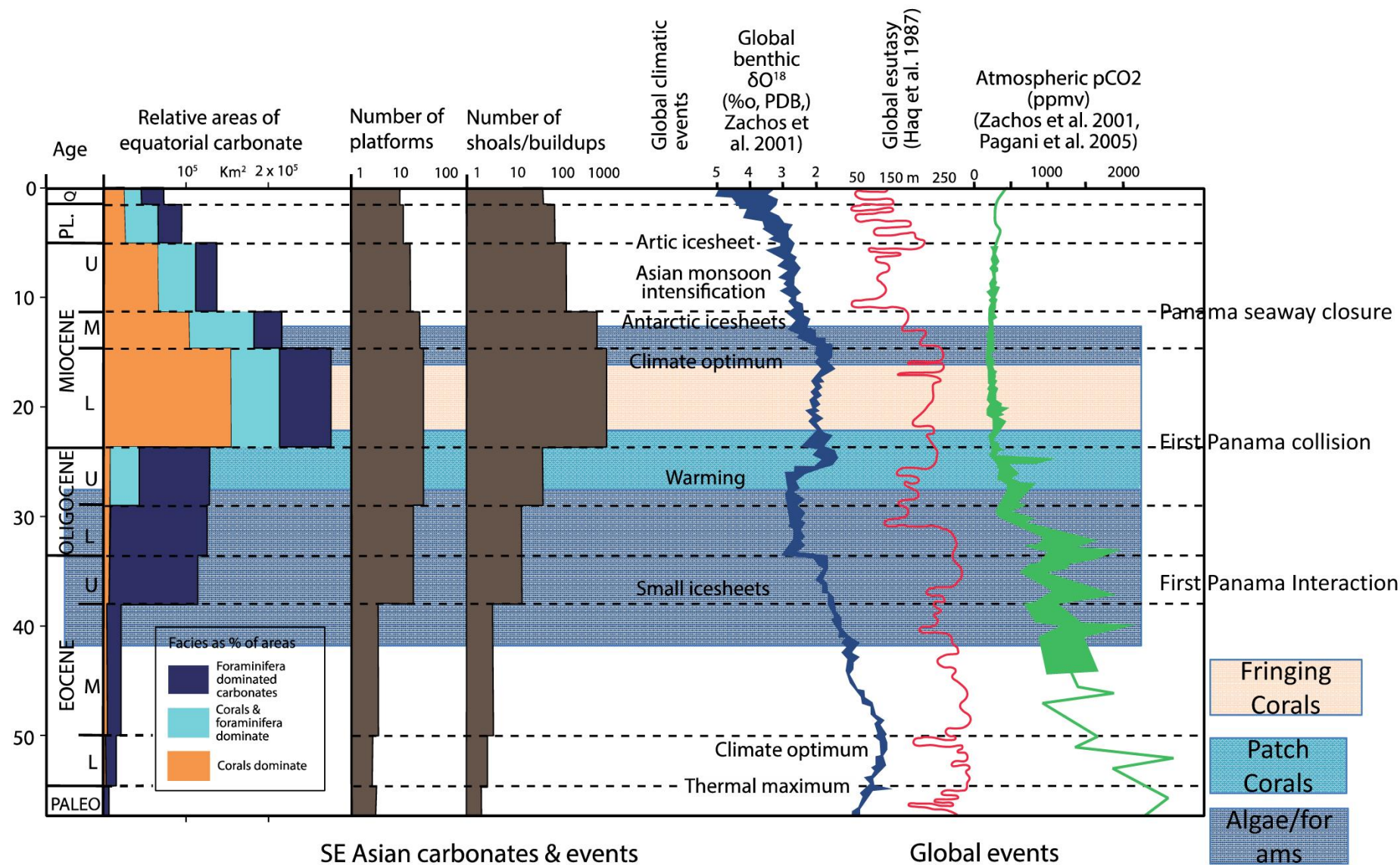
- Middle-Late Miocene Carbonates (Cachirimpa)
- Middle-Late Miocene Carbonates (Parajimaru)



Porosities 20-25%



Climate, in part, seems to have had some global control!!!

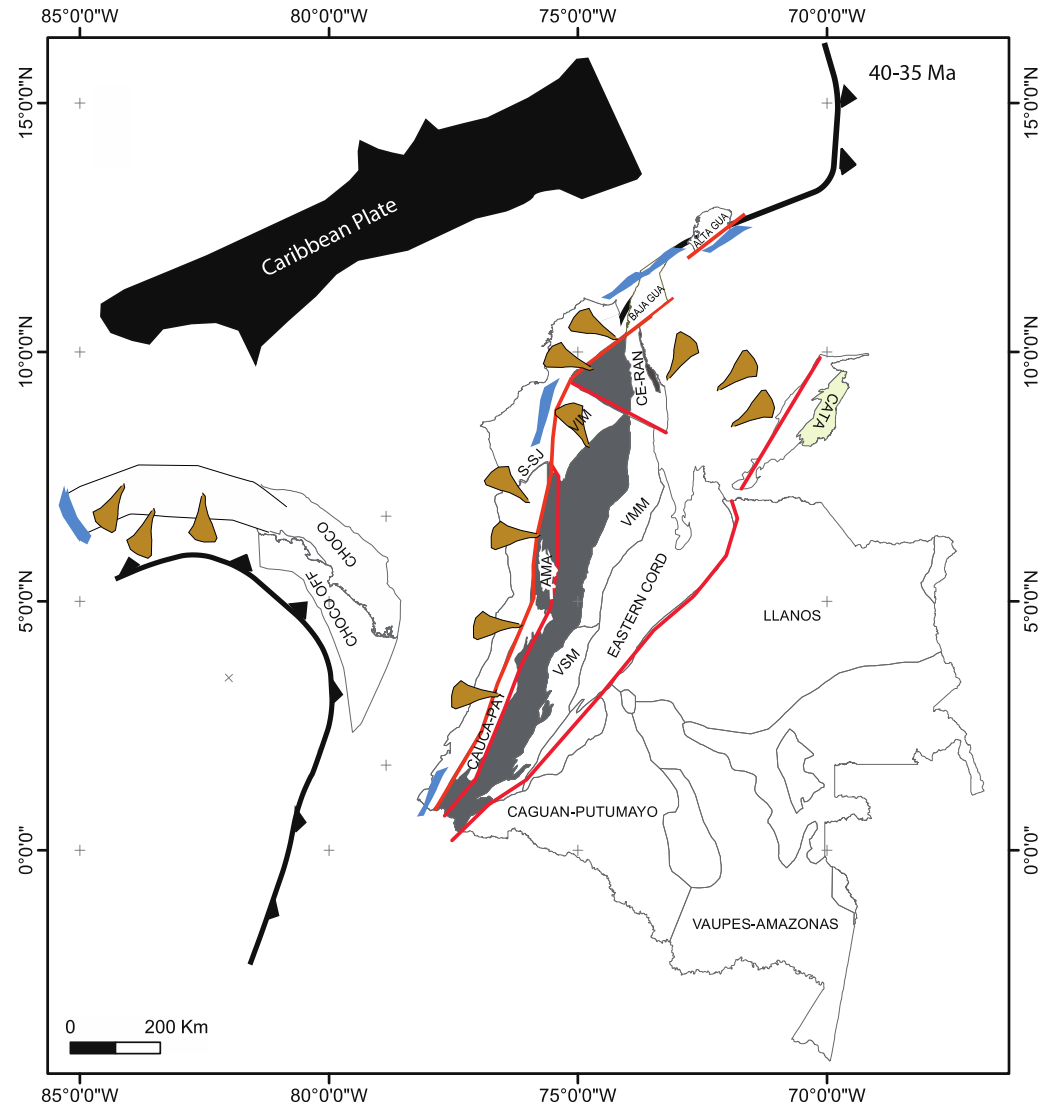


# Eocene-Oligocene



(Rhodalgal/Foraminifera factory)

High input of siliciclastics  
High temperature  
Relatively high sea level  
Moderate porosities





# Middle Oligocene



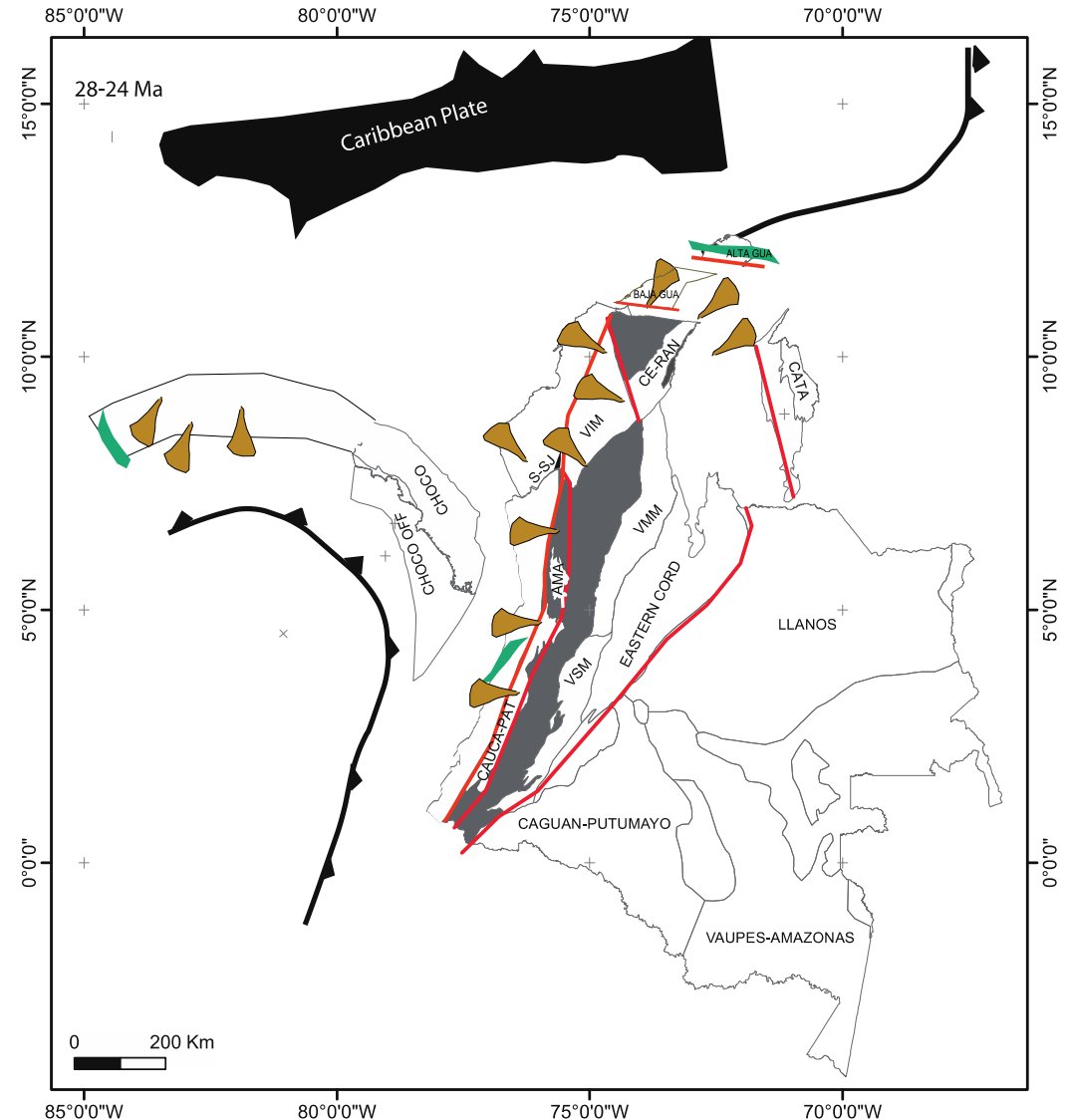
(Patch corals / rhodalgae)

High input of siliciclastics

Decreasing temperatures

Decreasing sea level

Low porosities

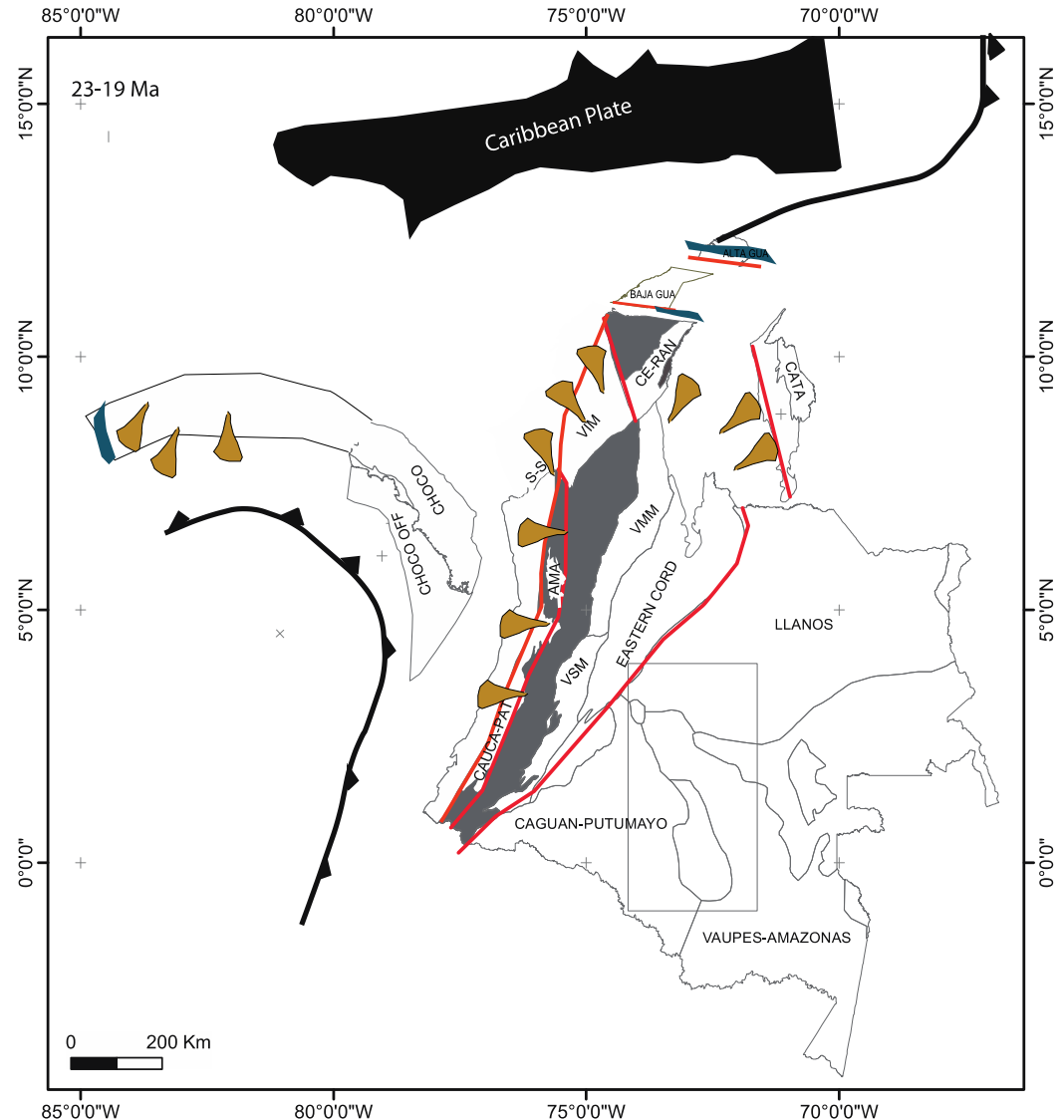


# Late Oligocene Early Miocene



(Fringing corals)

High input of siliciclastics  
First partial closure of Panama  
seaway  
Decreasing temperatures  
increase sea level  
low porosities





# Middle Miocene



(Rodalgal.large foraminifera)

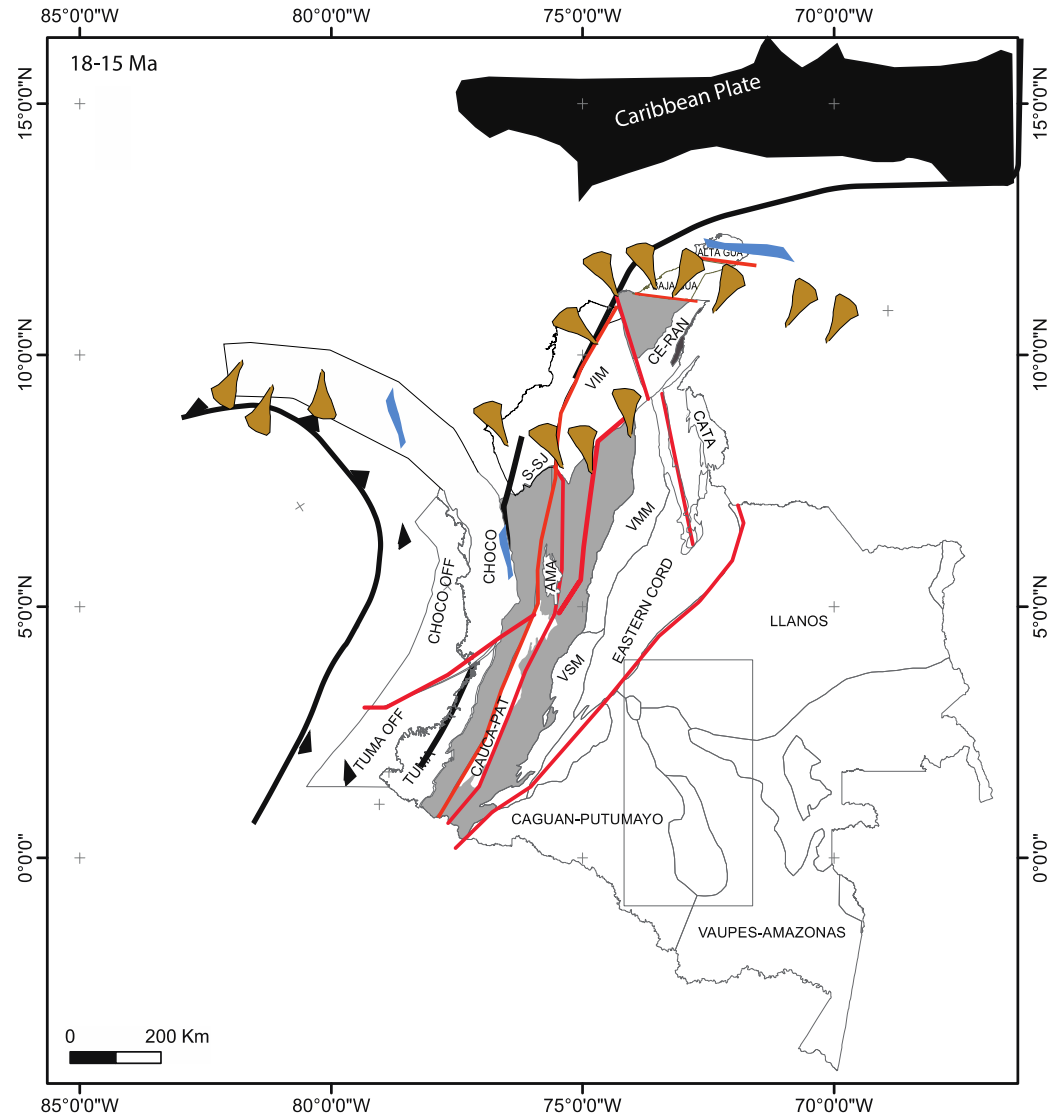
High input of siliciclastics

Final closure of Panama seaway

Increasing temperatures

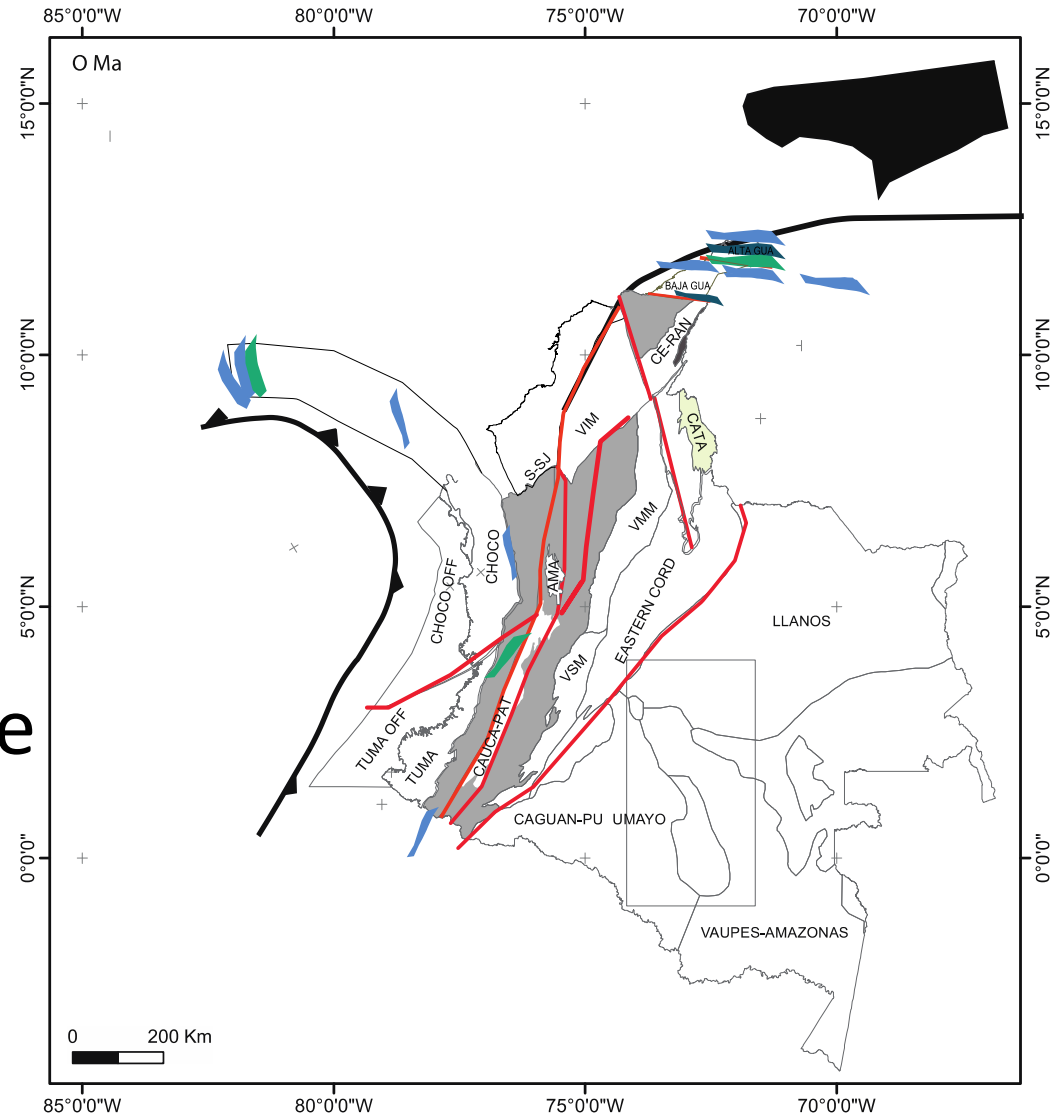
Increase sea level

High porosities



# Distribution

- Alta Guajira
  - Eocene
  - Oligocene
  - Miocene
- San Jacinto
  - Eocene-Oligocene
- Panama
  - Eocene
  - Miocene





# Summary

- There seems to be a similar evolution of reefs in the tropics
- Local tectonics seems to have affected the carbonate fabric
- Their occurrence in the Caribbean affected by local tectonics and the closure of the Panama seaway
- Excellent reservoirs are associated with early-middle Miocene coralline algae

# QUESTIONS?

