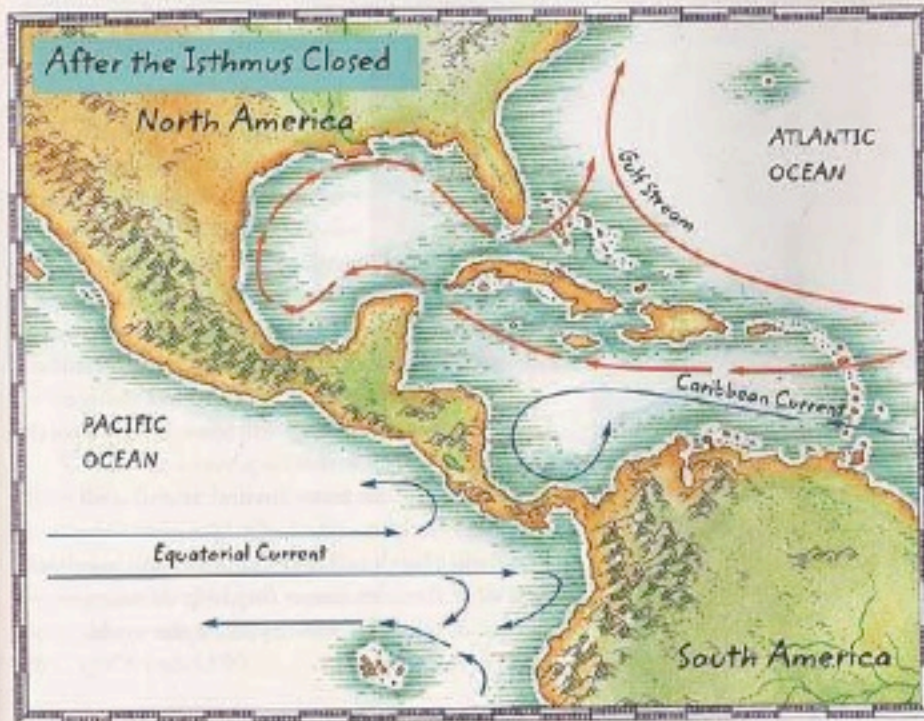
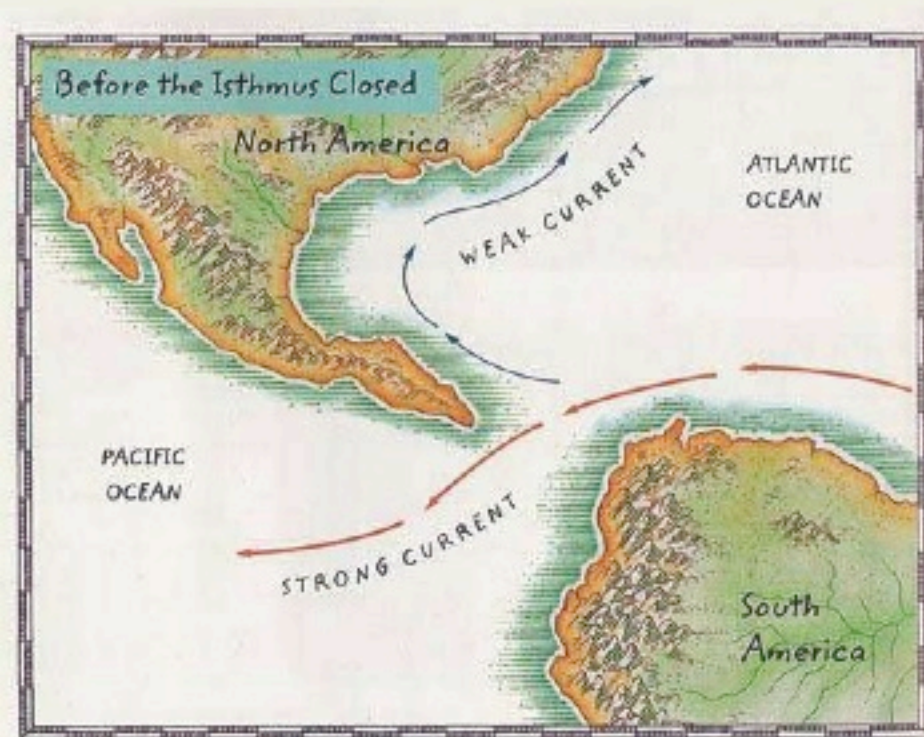


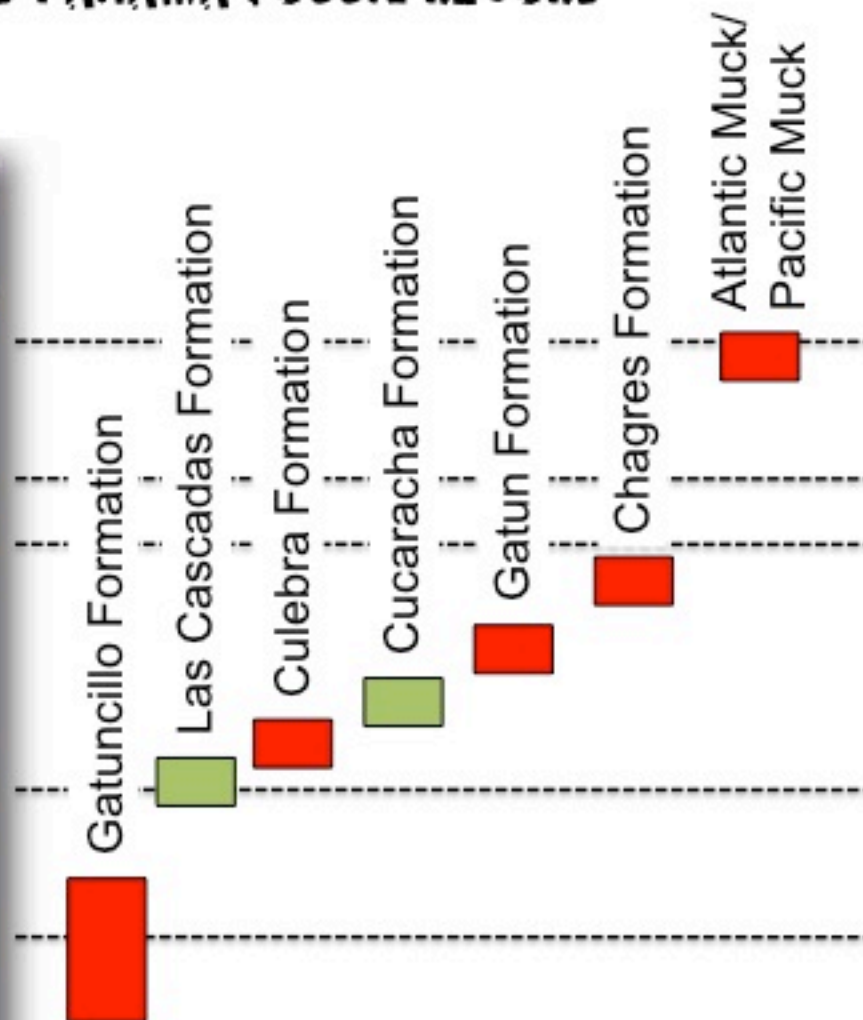
# Invertebrate fossils of Panama:

A 40 million year history of an ocean gateway

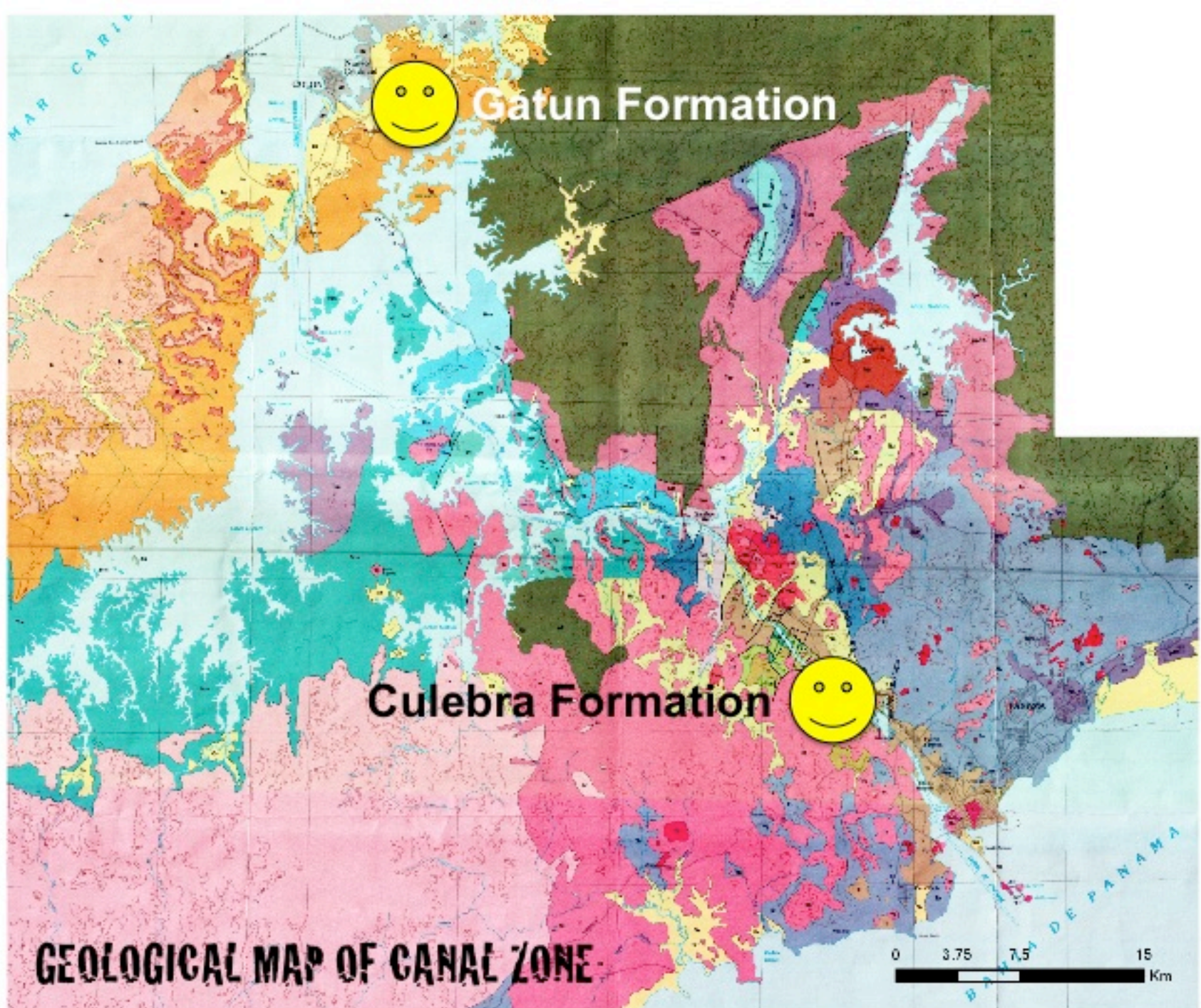


# GEOLOGICAL TIME SCALE AND PANAMA FOSSIL RECORD

Era	Period	Epoch	Time Scale
CENOZOIC	QUATERNARY	HOLOCENE	Present
		PLEISTOCENE (ICE AGE)	10,000 years ago
	TERTIARY	PLIOCENE	1.8 million years ago
			5.3 million years ago
		MIOCENE	
			23.8 million years ago
		OLIGOCENE	
			33.7 million years ago
		EOCENE	
			54.8 million years ago
	PALEOGENE	PALEOCENE	65 million years ago









**LATE EOCENE-LATE OLIGOCENE**

**- 25-40 million years ago**



**EARLY MIOCENE - 19-21 million years ago**





**LATE MIOCENE (Colon)**  
– 12–9 million year ago



**LATE MIOCENE-PLEISTOCENE (Bocas)**  
– 8–1 million years ago





PLEISTOCENE CRABS





EOCENE ECHINODERMS





## **MIOCENE SEA STAR**



## **OLIGOCENE AND MIOCENE BRACHIOPODS**





**MIOCENE NAUTILUS**



**MIOCENE BIVALVES AND GASTROPODS**





# THE GATUN FORMATION - GEOLOGY

- The Gatun Formation accumulated during the Late Miocene (11.8-5.2 million years ago).
- The fossils at Residencia San Judas are approximately 11 million years old.
- The formation was deposited during a phase of tectonic subsidence (the sedimentary basin was sinking).
- It rests upon Oligocene rocks with an unconformable contact (meaning time is missing). It is overlain unconformably by later Miocene rocks (Chagres Formation)

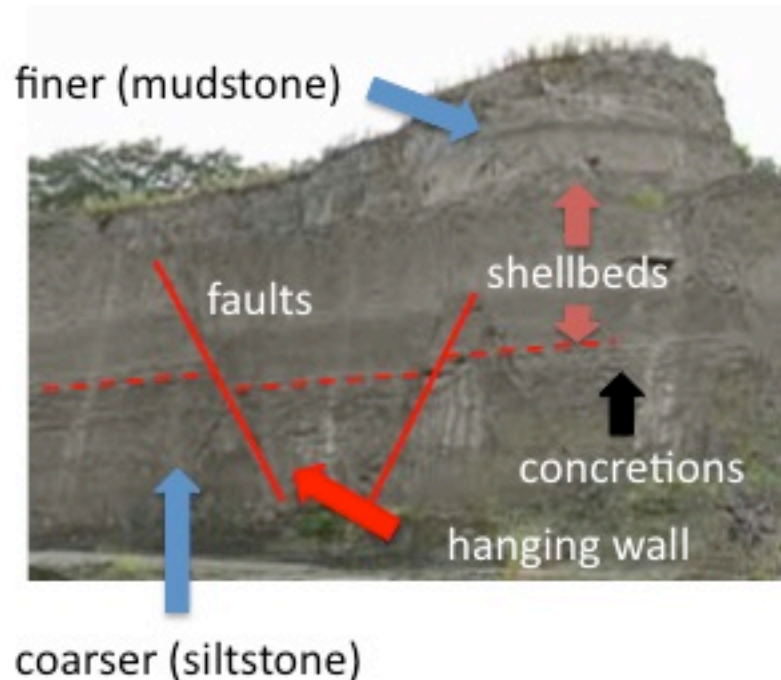
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		PALEOCENE	65 million years ago
	PALEOGENE		

Gatun  
Formation



# THE GATUN FORMATION - GEOLOGY

- The sequence of sediments at Residencia San Judas likely accumulated over tens to hundreds of thousands of years, and represent a number of fluctuations in sea-level.
  - The fine sediments at the very top of the section likely accumulated in deepest water.
  - Cemented (hardened) shell-beds near the base of the section, and the concretions (hard round blocks of sediment) probably accumulated when sea level was lowest.
- Numerous normal faults (where the hanging wall has moved downward) can be observed, and indicate that the basin experienced extension (stretching) after accumulation of the Gatun Formation.





# THE GATUN FORMATION - PALEOENVIRONMENTS

- The Gatun Formation at Residencia San Judas was deposited in shallow offshore (10-50 m) marine environments, proximal to the coastline, although in relatively low wave and current energy. The sediments are typically siltstone (fine-grained, but gritty to touch), and burrows are not easily observed.
- Characteristic taxa of these paleoenvironments include: *Anadara dariensis*, *Panchione mactropsis*, *Turritella attilira*, *Cymatophos veatchi*, and many *Conus*.





# THE GATUN FORMATION - PALEOECOLOGY

- Fossil invertebrate species of the Gatun Formation occupied a variety of ecological niches (ways of life).
- Many species are filter-feeders (or suspension-feeders), meaning that they derive their nutrition by filtering particulate organic material from water.
  - Some of these live above the sediment-water interface (known as an *epifaunal* life-habit). Being epifaunal allows an organism to be free of sediment that may bury or choke them, and to be exposed to currents that carry organic particles.
  - Other filter-feeding taxa live below the sediment-water interface (referred to as an *infaunal* life-habit).



Epifaunal bivalve (scallop)



Infaunal bivalves (clams)



# THE GATUN FORMATION - PALEOECOLOGY

- Some species are deposit-feeders (or detritivores) that obtain nutrients by consuming detritus (decomposing organic matter). These are typically infaunal, but are more common in deeper environments.



Traces made by deposit-feeding bivalves

- The last common group of species are carnivores (predators or scavengers). Predators will actively seek out living prey and in most cases drill (boreholes) or chip the enclosing shell of the prey to access tissue.



Traces made by naticid-predator (upper center)



# THE GATUN FORMATION - PALEOECOLOGY

Infaunal suspension feeders:



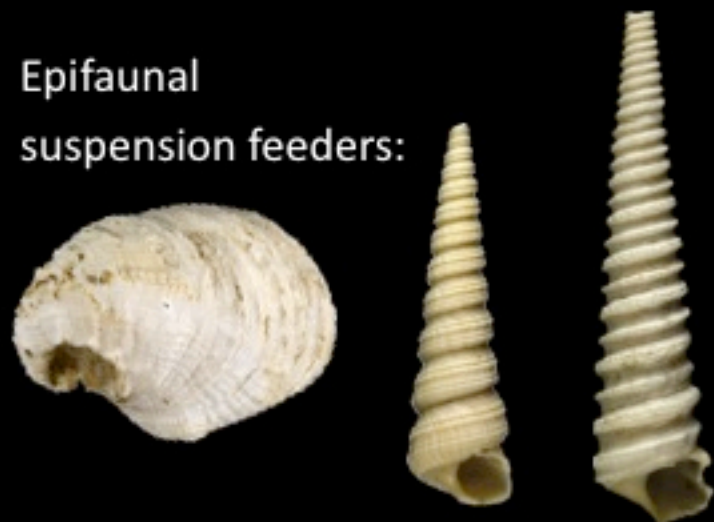
Semi-infaunal  
suspension feeders:



Infaunal  
deposit feeders:



Epifaunal  
suspension feeders:

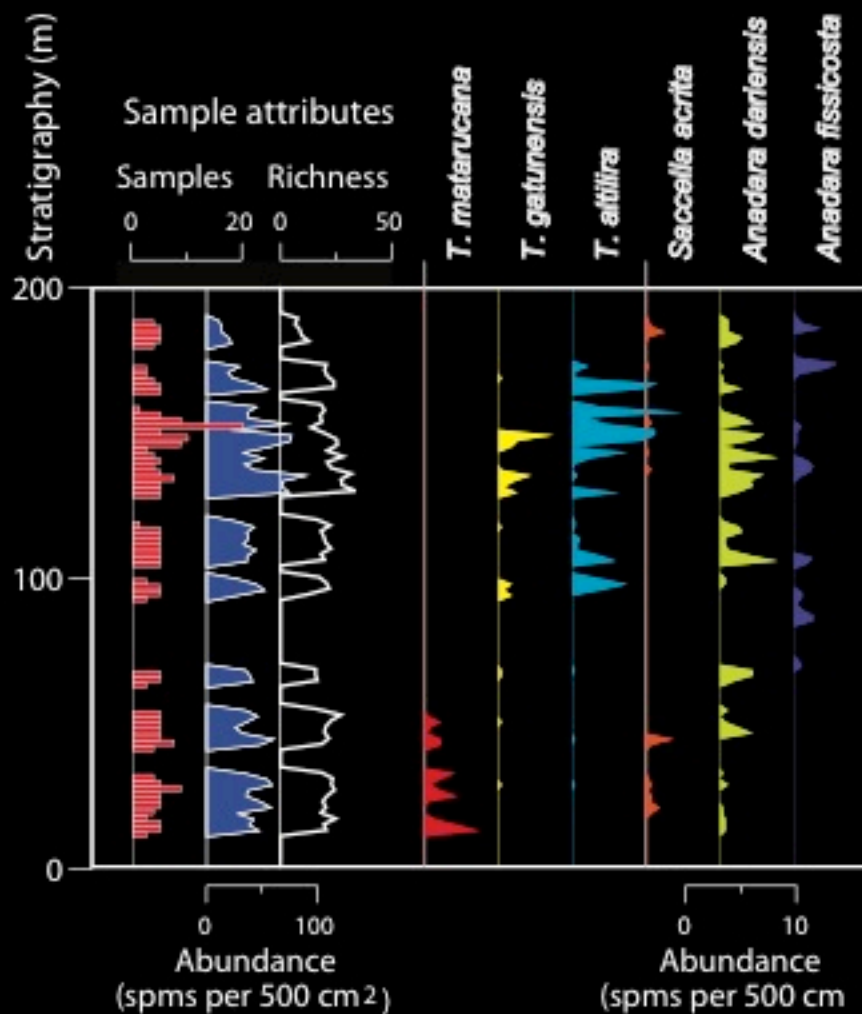


Predators/scavengers:



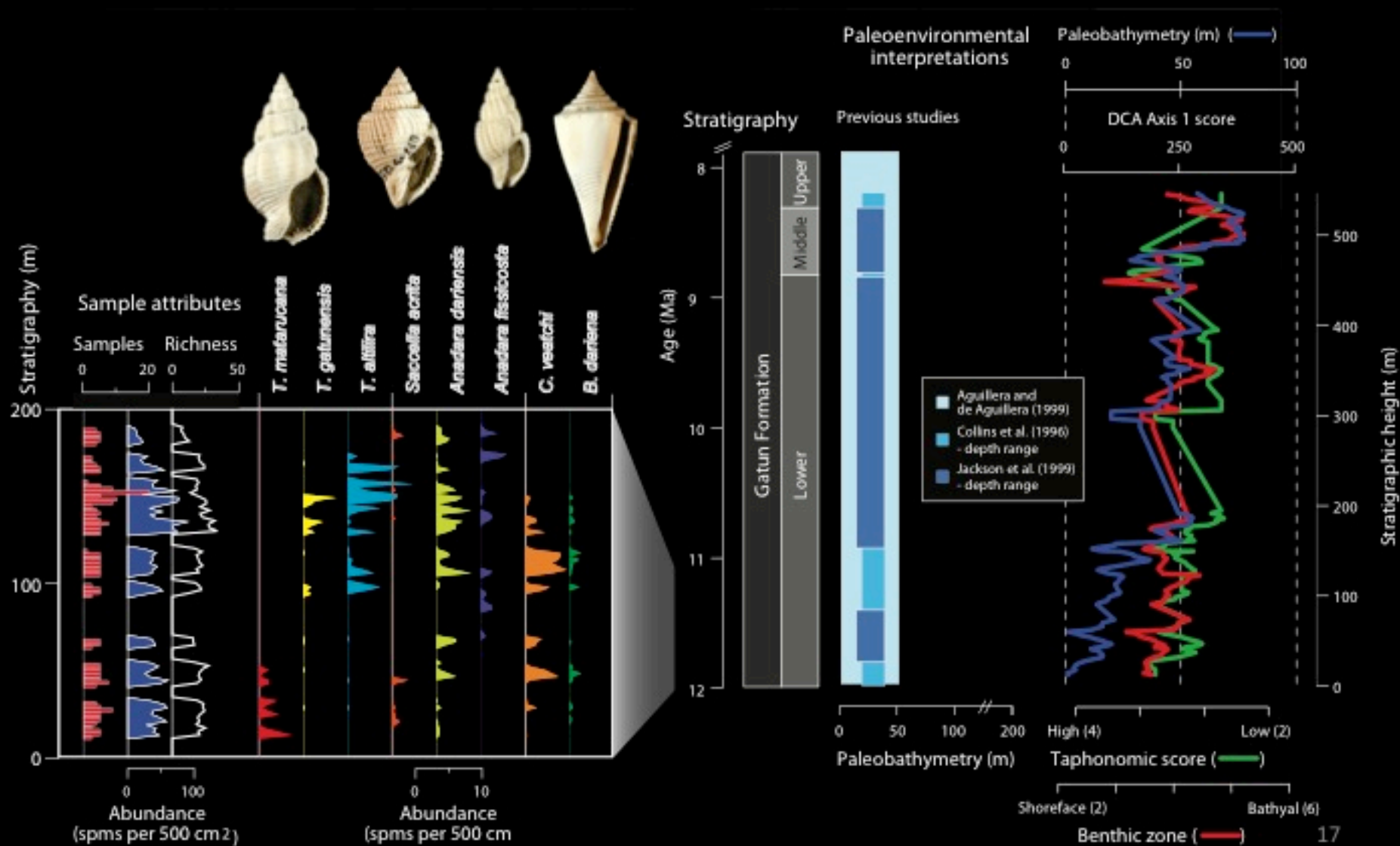


# THE GATUN FORMATION - PALEOECOLOGY





# THE GATUN FORMATION - PALEOECOLOGY



# THE GATUN FORMATION - BIOGEOGRAPHY



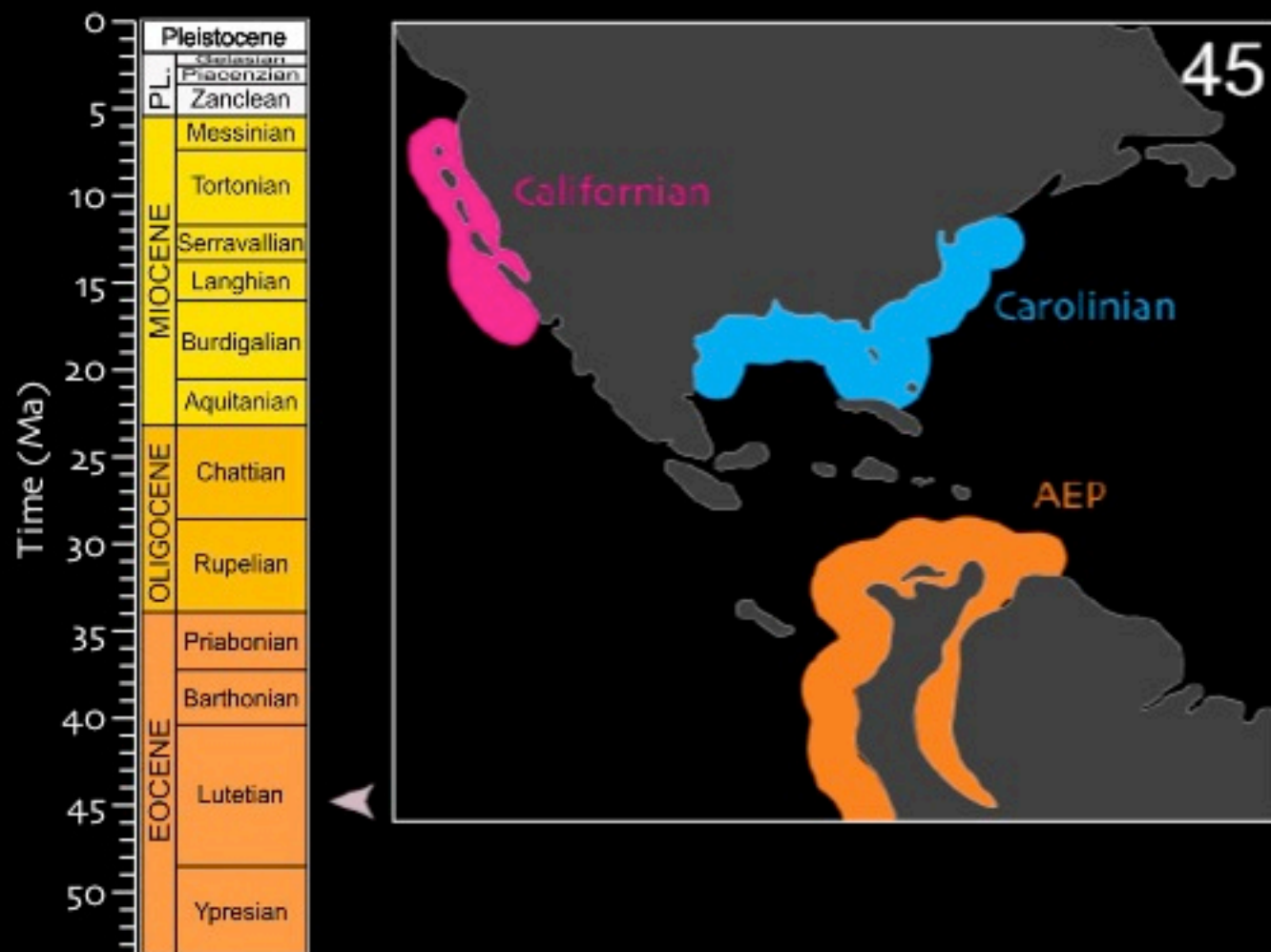


# THE GATUN FORMATION - BIOGEOGRAPHY

- Statistical comparison of the taxonomic composition of faunal assemblages.
- Assemblages that are similar to one another are defined as biogeographic provinces.
- The distribution of biogeographic provinces are then plotted on paleogeographic maps.



# THE GATUN FORMATION - BIOGEOGRAPHY



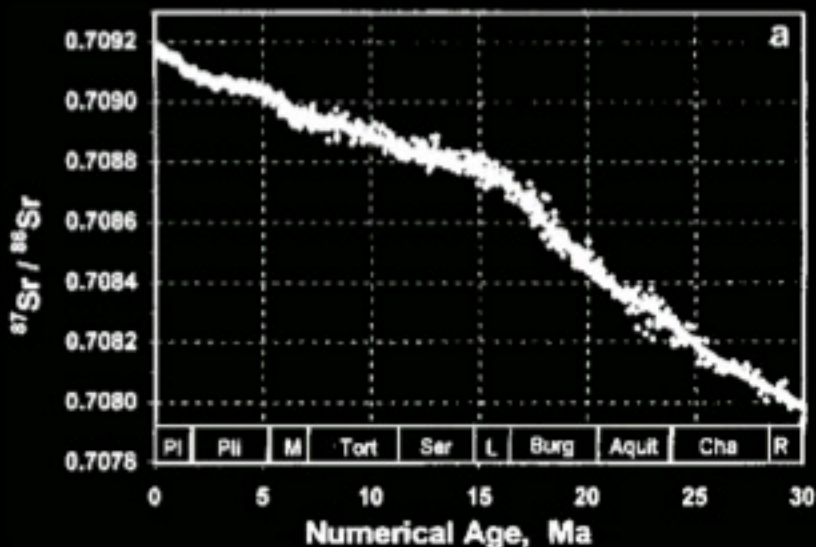


# THE GATUN FORMATION - AGE

- Absolute dating methods
  - Strontium isotope ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) dating (11.5-9.1 Ma)
  - Uranium-lead ( $^{238}\text{U}/^{206}\text{Pb}$ ) dating of igneous (volcanic) rocks ( $8.24 \pm 0.15$  Ma)
  - Argon-Argon ( $^{40}\text{Ar}/^{39}\text{Ar}$ ) dating of igneous (volcanic) rocks (9-9.8 Ma)



- Relative dating methods:
  - macrofossil biostratigraphy (early late Miocene, 12-8 Ma)
  - microfossil biostratigraphy (NN8-NN10 = 11.0-8.6 Ma)



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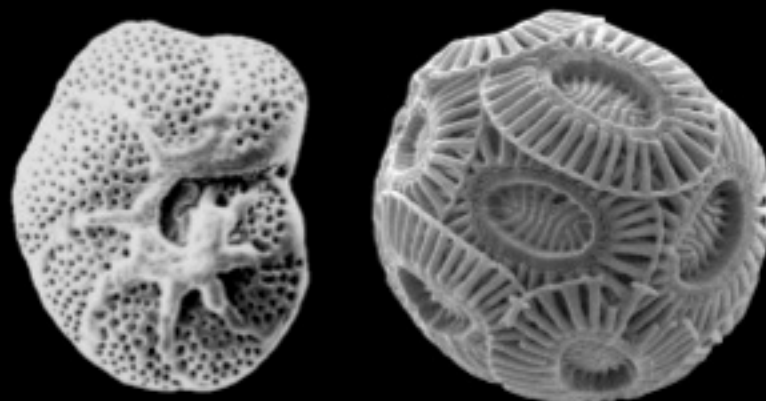
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FAUNAL CHRONOLOGICAL SCALE				CALCAREOUS NANNOFOSSIL BIOSTRATIGRAPHY			
Chrono stratigraphy				Okada & Bukry (1980), emend.	Boundary events	Martini (1971)	Boundary events
Ma	Class	Polarity					
1	Ctr			CN13	b	NN19	
2	Ctr				median <i>Gephyrocapsa</i> <i>D. brevis</i>	NN18	<i>D. brevis</i>
3	Ctr				<i>D. postcarduata</i> <i>D. carduata</i>		<i>D. postcarduata</i> <i>D. carduata</i>
4	Ctr			CN12	ab	NN16	
5	Ctr				<i>Gephyrocapsa</i> spp. <i>D. postcarduata</i>	NN14-NN15	<i>D. postcarduata</i>
6	Ctr			CN11	a	NN13	<i>D. asymmetrica</i>
7	Ctr				<i>A. princeps</i> <i>C. rugosa</i> <i>C. alba</i>	NN12	<i>C. rugosa</i>
8	Ctr			CN10	b		<i>D. postcarduata</i>
9	Ctr				<i>D. postcarduata</i> <i>A. princeps</i> <i>A. princeps</i>		<i>D. postcarduata</i>
10	Ctr			CN9	ba	NN11	<i>A. princeps</i>
11	Ctr				<i>A. princeps</i>		<i>A. princeps</i>
12	Ctr				<i>D. longirostris</i> <i>D. longirostris</i>	NN10	<i>D. longirostris</i>
13	Ctr			CN8	a		<i>D. longirostris</i>
14	Ctr				<i>D. longirostris</i>	NN9	<i>D. longirostris</i>
15	Ctr			CN7	a+b		<i>D. longirostris</i>
16	Ctr				<i>D. longirostris</i> <i>C. ovalis</i> <i>D. longirostris</i>	NN8	<i>C. ovalis</i>
17	Ctr			CN6	b		
18	Ctr				<i>D. longirostris</i>	NN7	<i>D. longirostris</i>
19	Ctr			CN5	a	NN6	<i>D. longirostris</i>
20	Ctr				<i>D. longirostris</i>		<i>D. longirostris</i>
21	Ctr				<i>D. longirostris</i>	NN5	<i>D. longirostris</i>
22	Ctr			CN4			<i>D. longirostris</i>
23	Ctr				<i>D. longirostris</i> <i>D. longirostris</i>		<i>D. longirostris</i>
24	Ctr				<i>D. longirostris</i>		<i>D. longirostris</i>
25	Ctr				<i>D. longirostris</i>		<i>D. longirostris</i>
26	Ctr				<i>D. longirostris</i>		<i>D. longirostris</i>