# Holocene Accretion Rates and Styles for Caribbean Coral Reefs: Lessons for the Past and Future*

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## Abstract

Long-standing models hold that, since the advent of a symbiotic relationship between corals and photosynthetic zooxanthellae, reefs close to sea level have been capable of accreting at rates (up to 14 m/1000 yrs) that exceed normal sea-level rise (<10 m/1000 yrs). These same models assume that reef building is largely a biological process that results in a framework dominated by in-place corals. Because of the strong photosynthetic ties, accretion will decrease dramatically with water depth and failing light. All of this is contrary to common reports of reef drowning, and resolution of this "paradox" has invoked either sudden, large jumps in sea level or dramatic reductions in water quality that hampered calcification.

A closer examination of reef-accretion data has revealed that Caribbean reefs build much more slowly than has been assumed (avg. ~ 3.5 m/1000 yrs). While rates from the Great Barrier Reef and the wider Indo-Pacific region are faster, most reefs still built slower than 4 m/1000 yrs and it was rare for reef accretion to approach twice that rate. Furthermore, reconstructions of paleo-water depths using the positions of dated samples in cores and widely accepted Holocene sea-level curves reveal little or no relationship between depth and reef-accretion rate in water shallower than 25-35 m. Data from exposed Holocene reefs in the western Dominican Republic support the findings based on cores. Prior to 7,000 CalBP, changes in reef-community structure reflected increasing water depth (i.e., SL rise > reef building). After 6,000 CalBP, this pattern reversed and shallow reefs dominated by finely branching *Acropora cervicornis* built seaward over the deeper forereef. This shift occurred when sea-level rise slowed to ca 3.5 m/1000 yrs - the average accretion rate computed for Caribbean reefs.

All of this bears on our ability to use Holocene reefs to model earlier ones, at least back to the Triassic. The fastest rates of Holocene sea-level rise could have easily left most Caribbean reefs behind without either sudden upward leaps or inimical bottom waters. Thus, patterns of reef accretion can provide a sensitive measure of relative sea-level rise looking into the past. At the same time, recent estimates of sea-level rise paint a disturbing picture of reefs very close to the point where they will no longer be able to keep up.

## References


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# Holocene Accretion Rates & Styles for Caribbean Reefs: Lessons for the Past & Future

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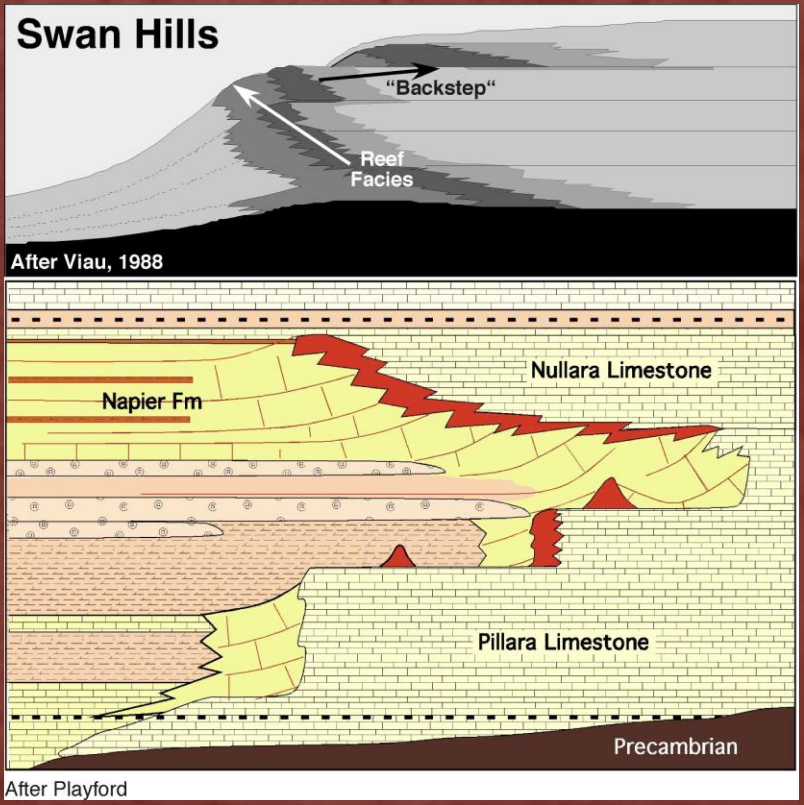
# The "Rules" of Reef Geometry

## Accretion vs Sea Level




| Production | GE Sea Level |
|---|---|
| ± | ± |
| Transport | "Tectonics" |

<u>BACKSTEPPING = abandonment → shift</u>

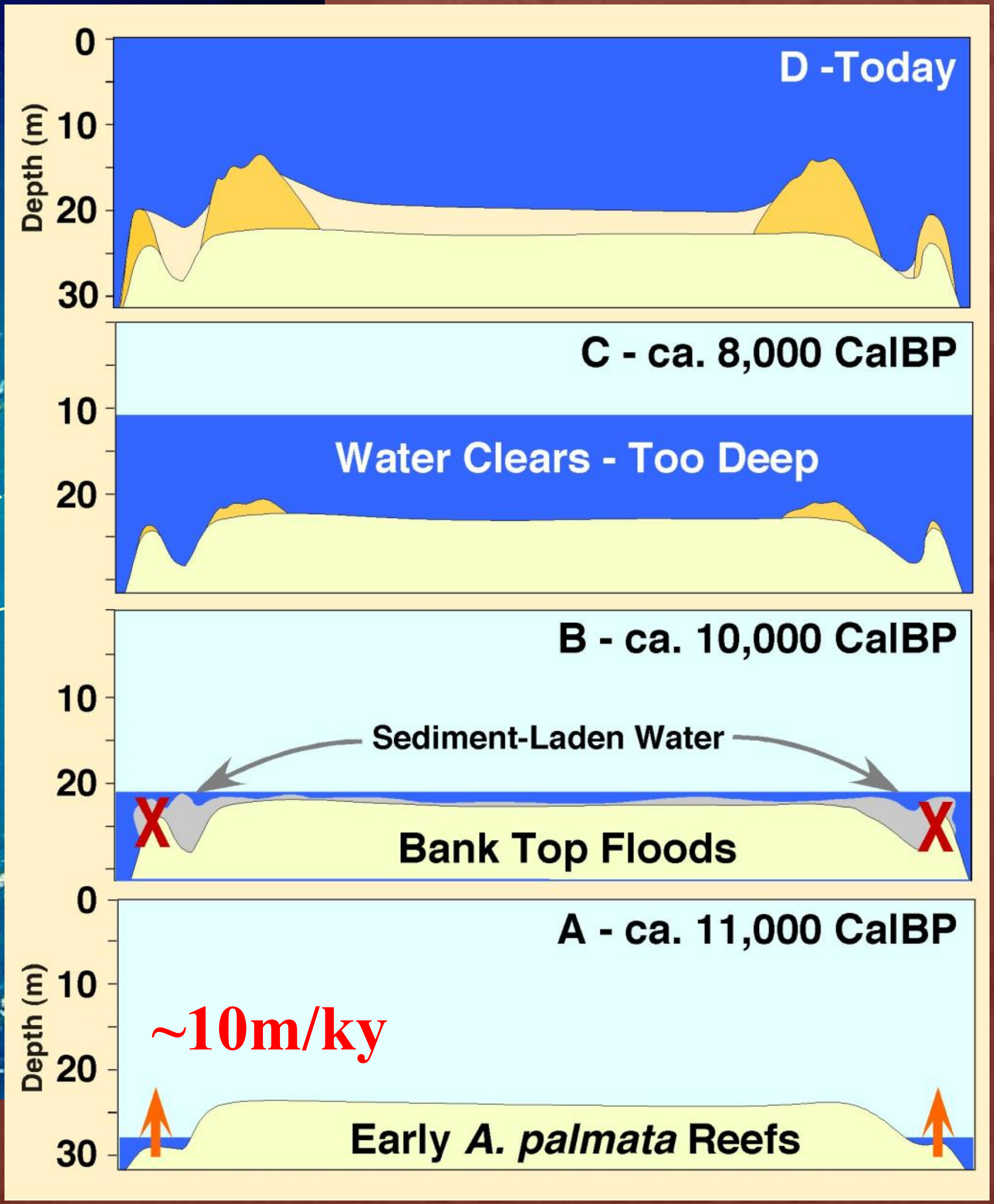
**It is generally tied to dramatic change**

Atlantic Ocean
Caribbean Sea
Lang
Bank
100 km
Google Earth
Data SIO, NOAA, US Navy, NCA, GFBCO


Lang Bank

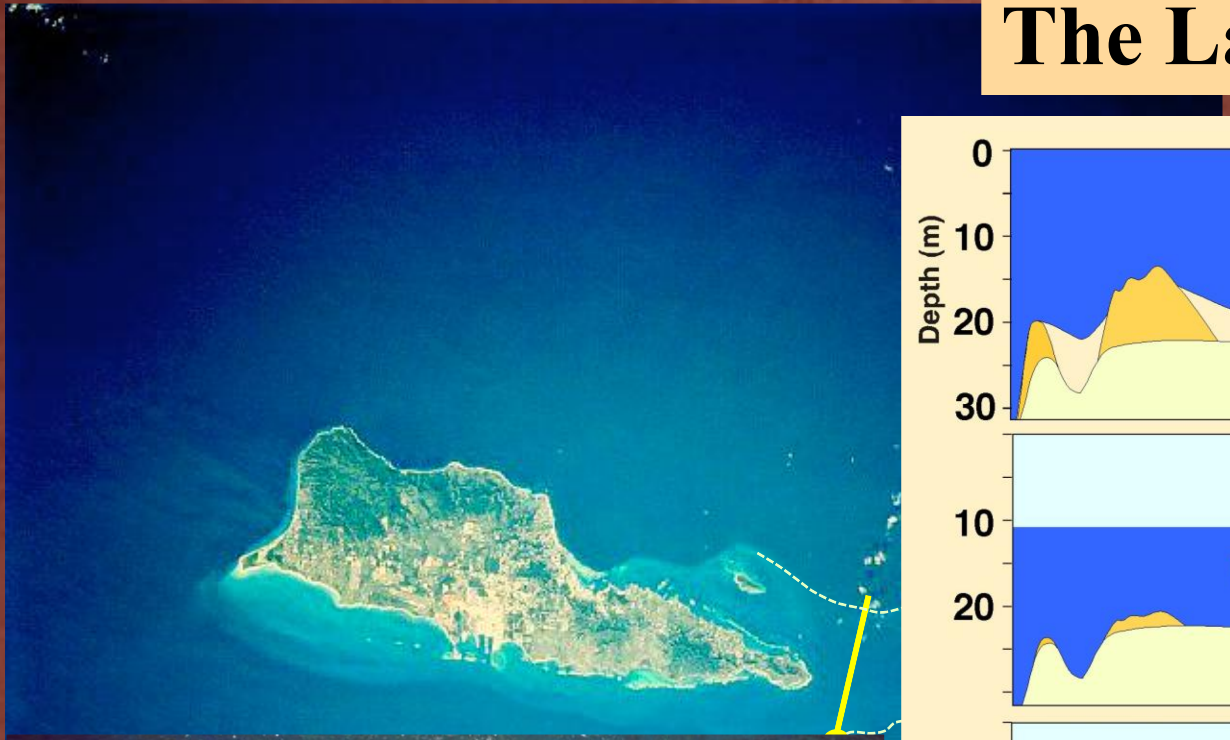

Adey et al. (1977)

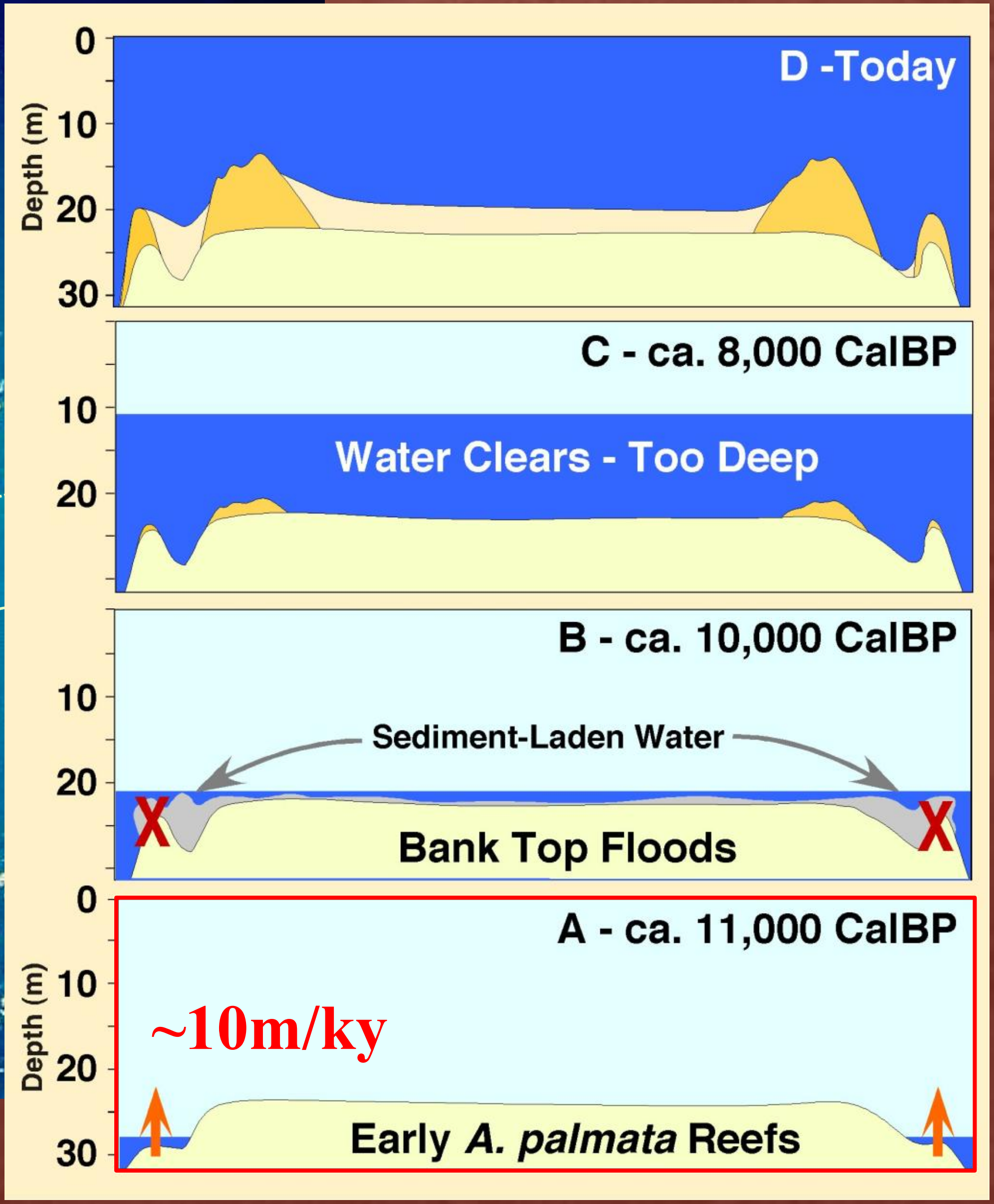
# The Lang Bank Story




After Adey et al. (1977)

# The Lang Bank Story



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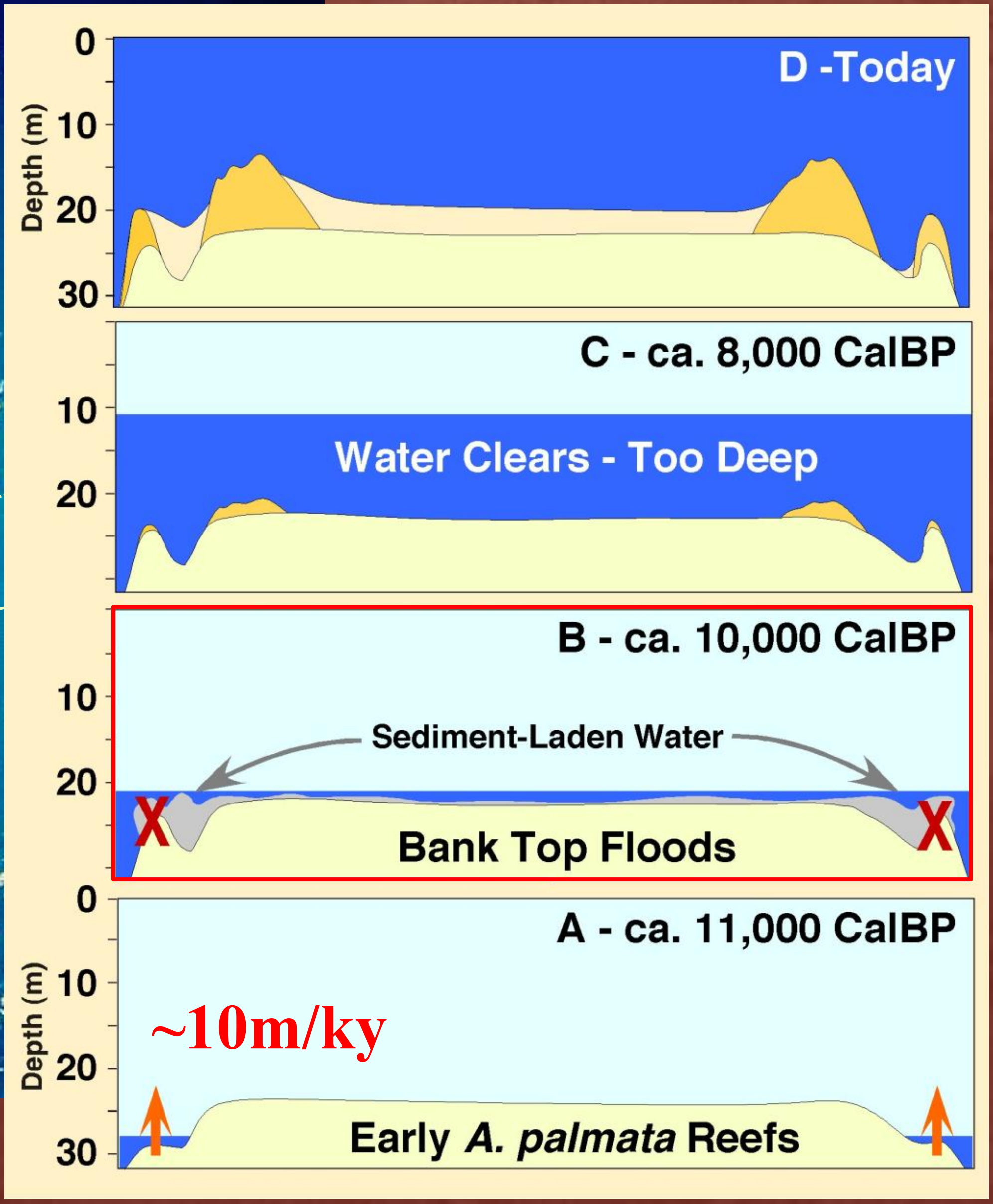


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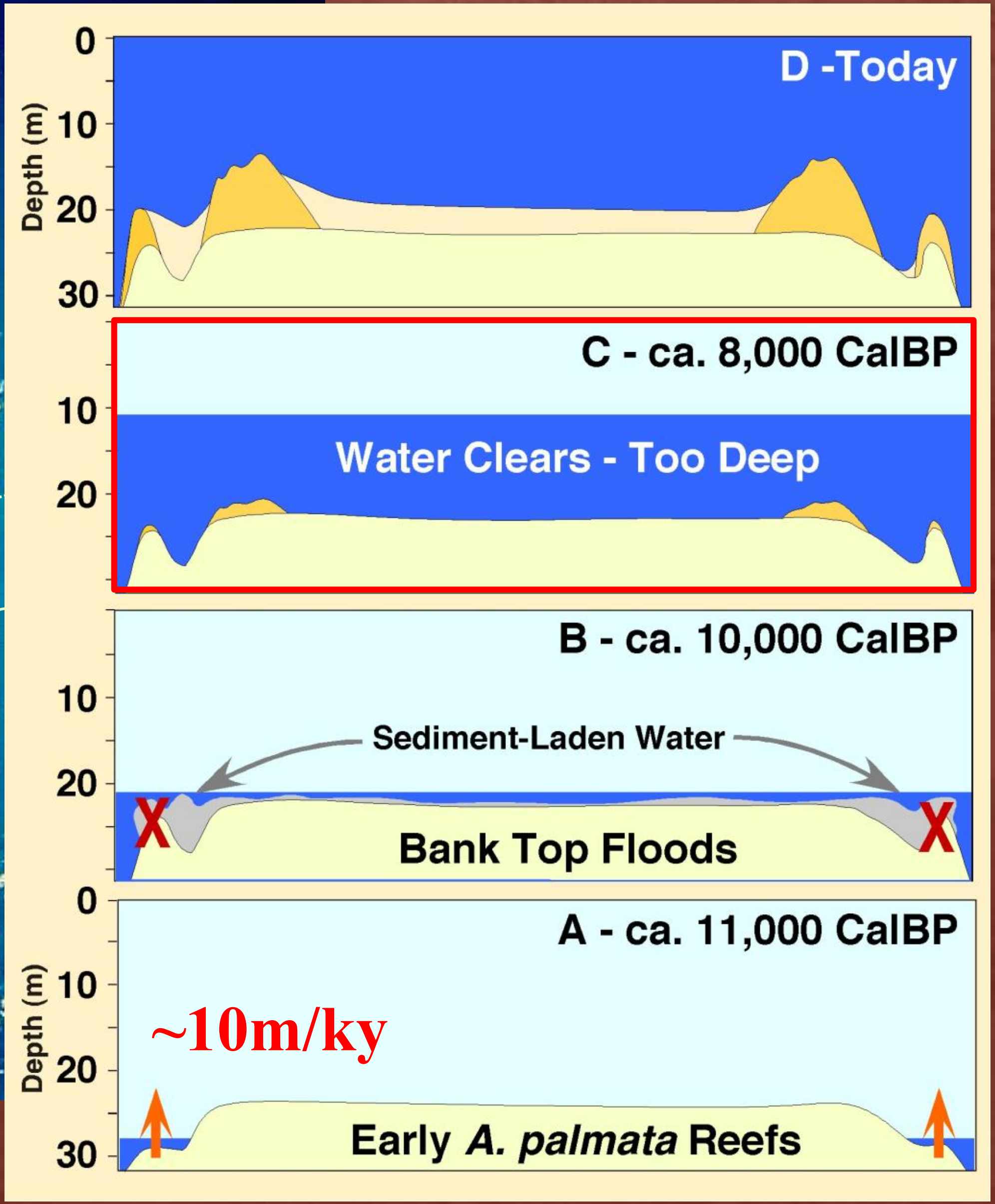


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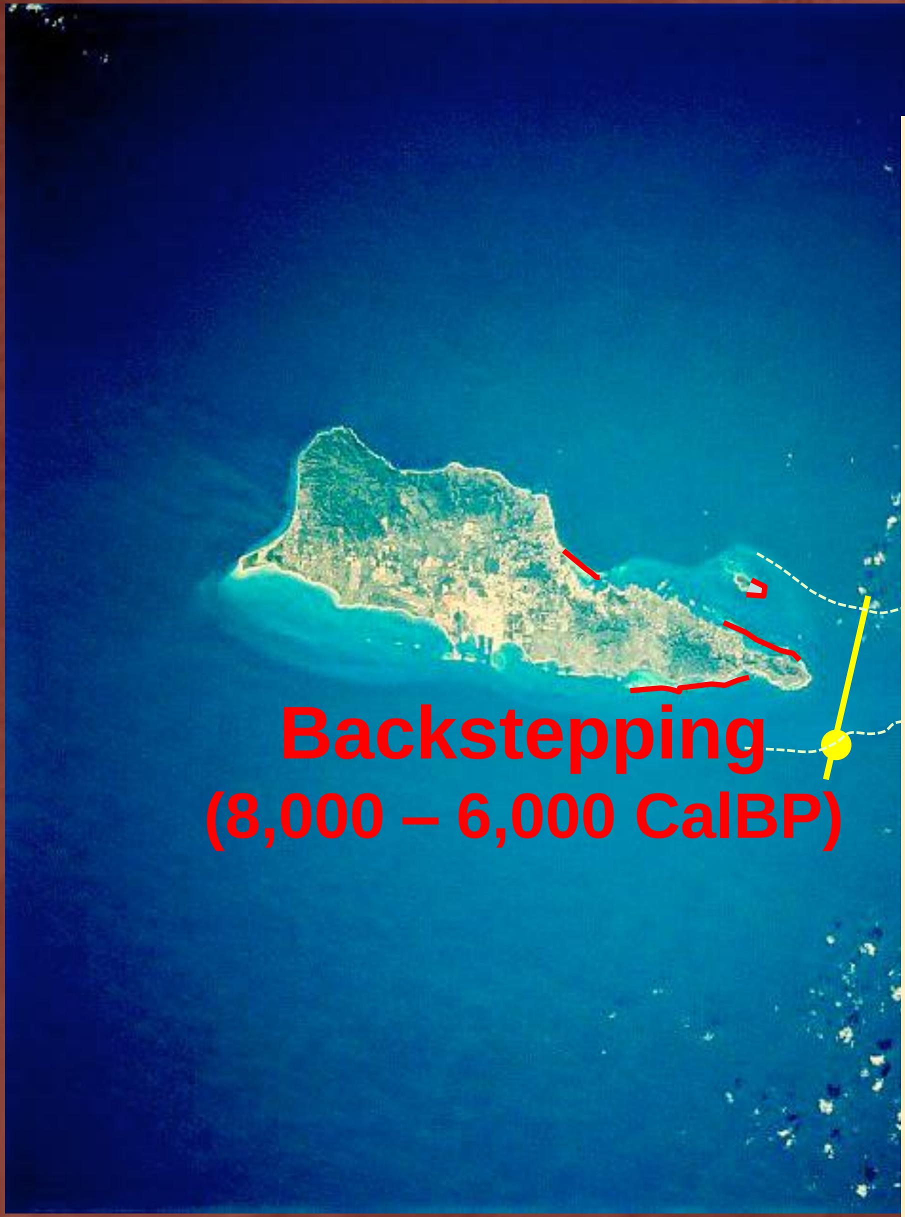
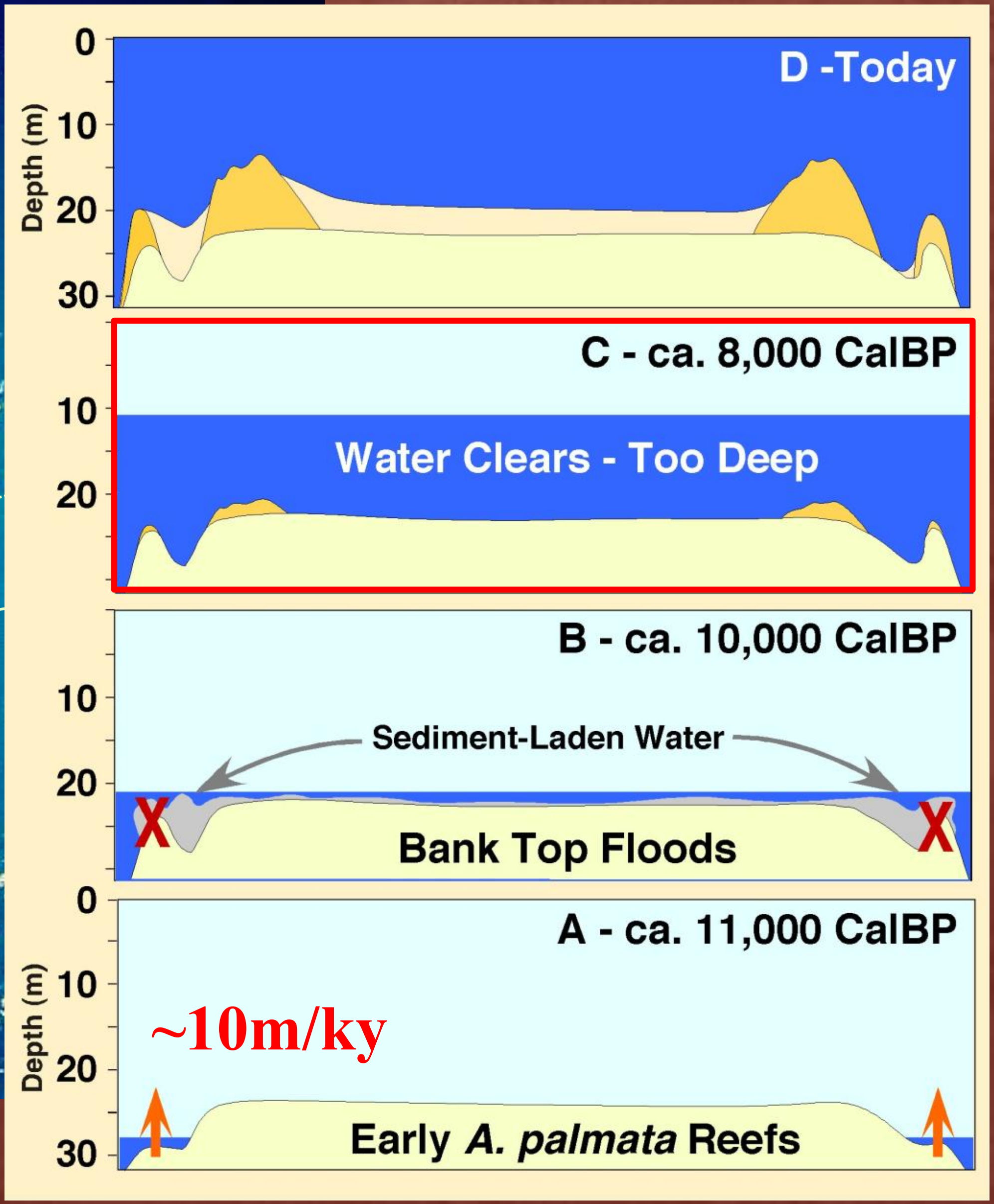



After Adey et al. (1977)

# Questions:

- What happened 10,000 years ago?
- How fast have reefs built in the Holocene?

- How does backstepping work?

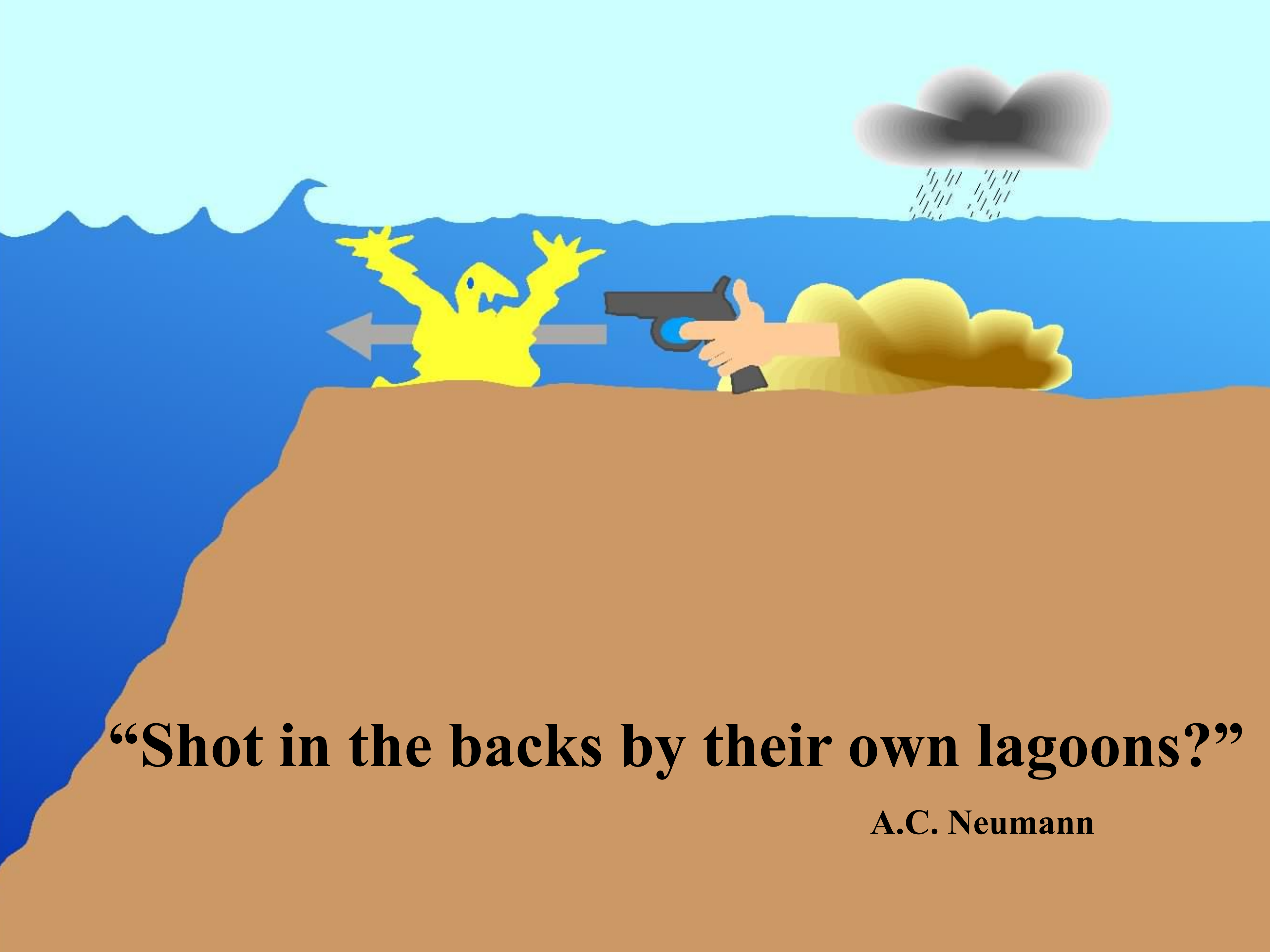
- Relevance to the past & the future?

***"Many Holocene reefs can be shown to have outpaced even the fastest sea-level rise."***

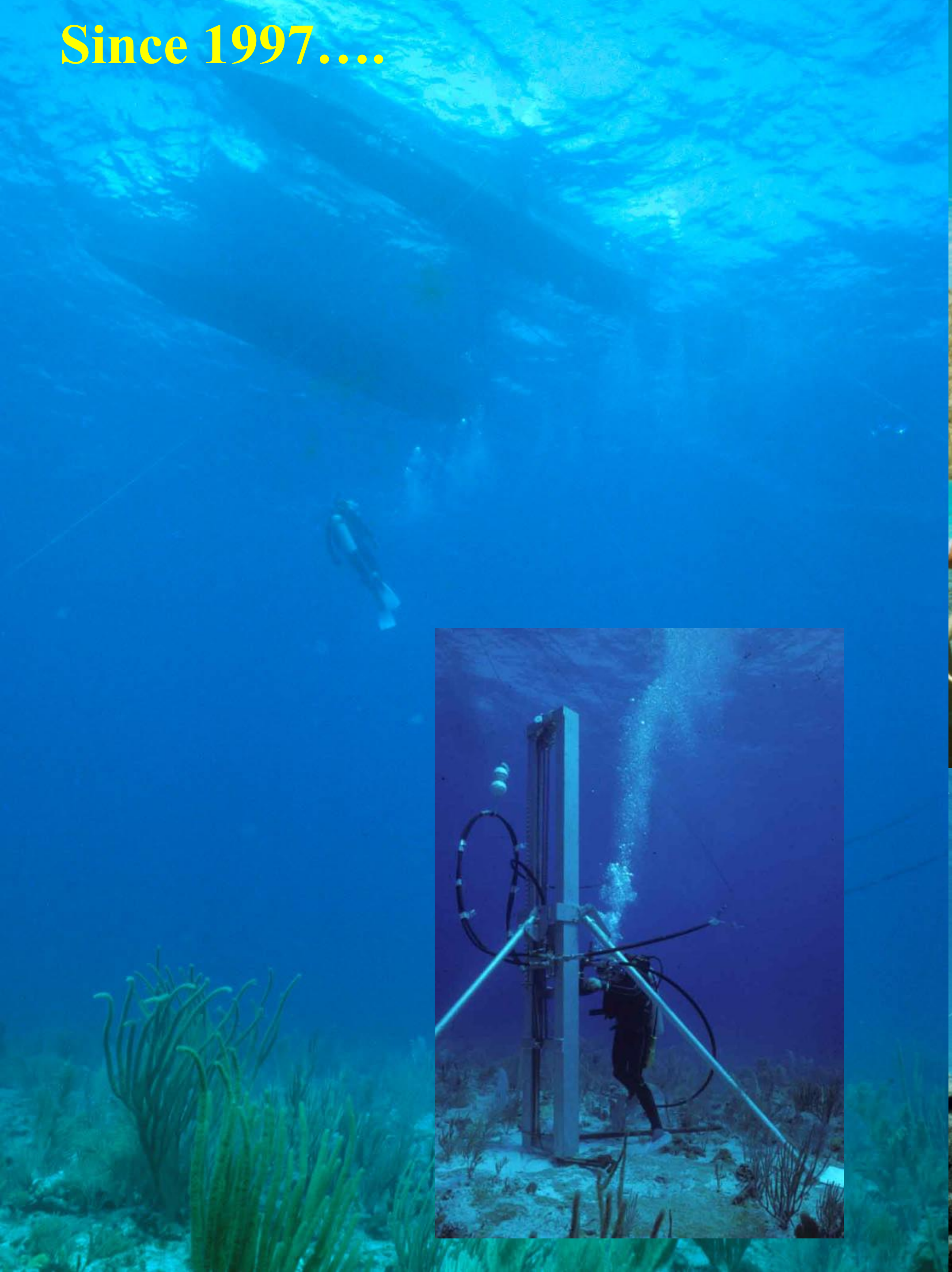
**Schlager (1989)**

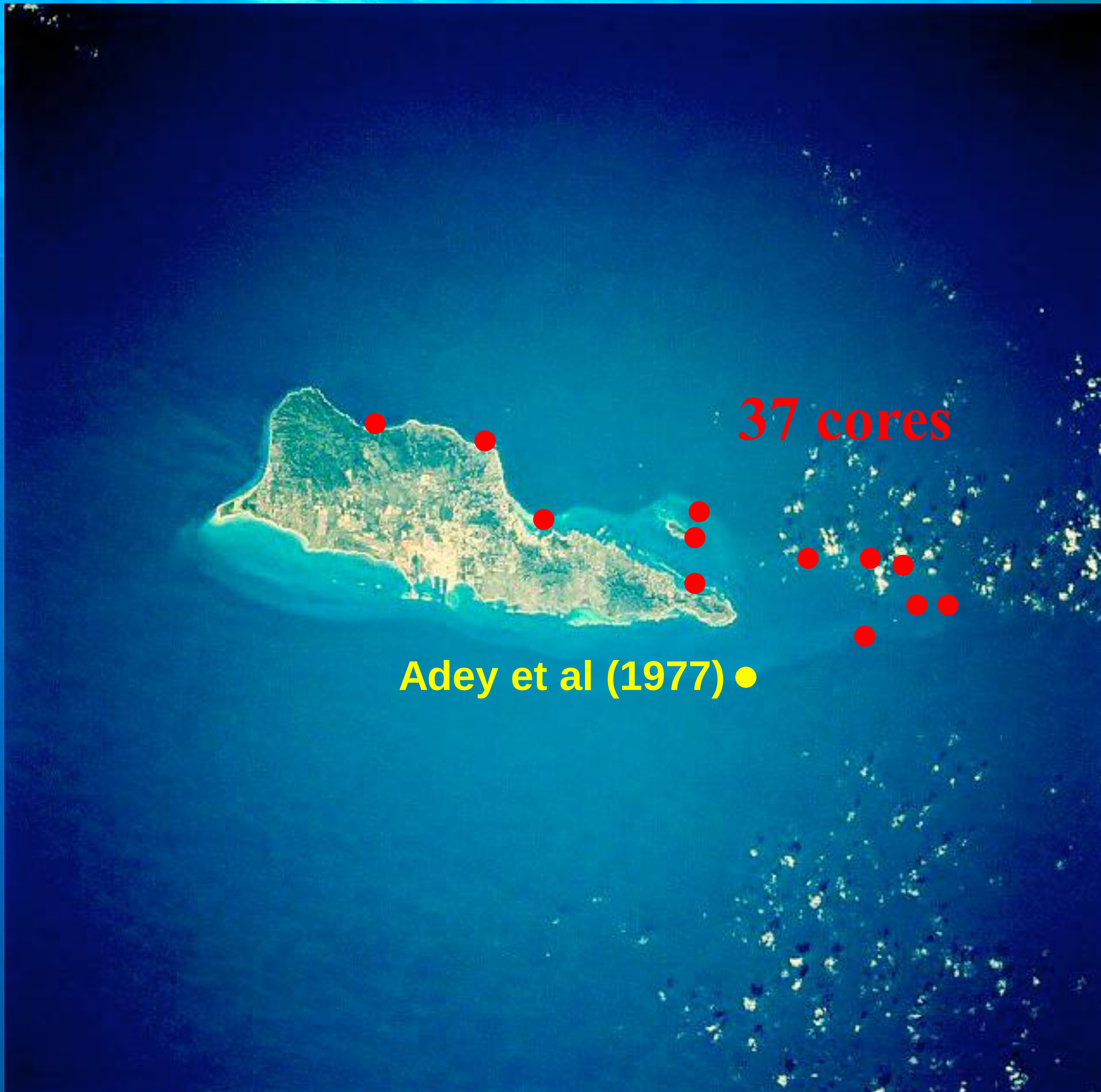
**$\leq 10$**

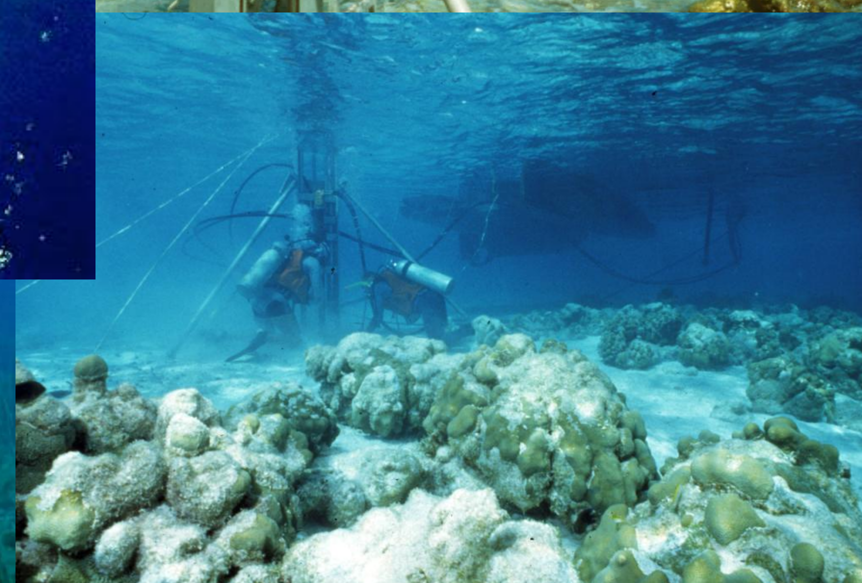

Too Little Light
A sudden jump….


"Shot in the backs by their own lagoons?"
A.C. Neumann

# Since 1997…..

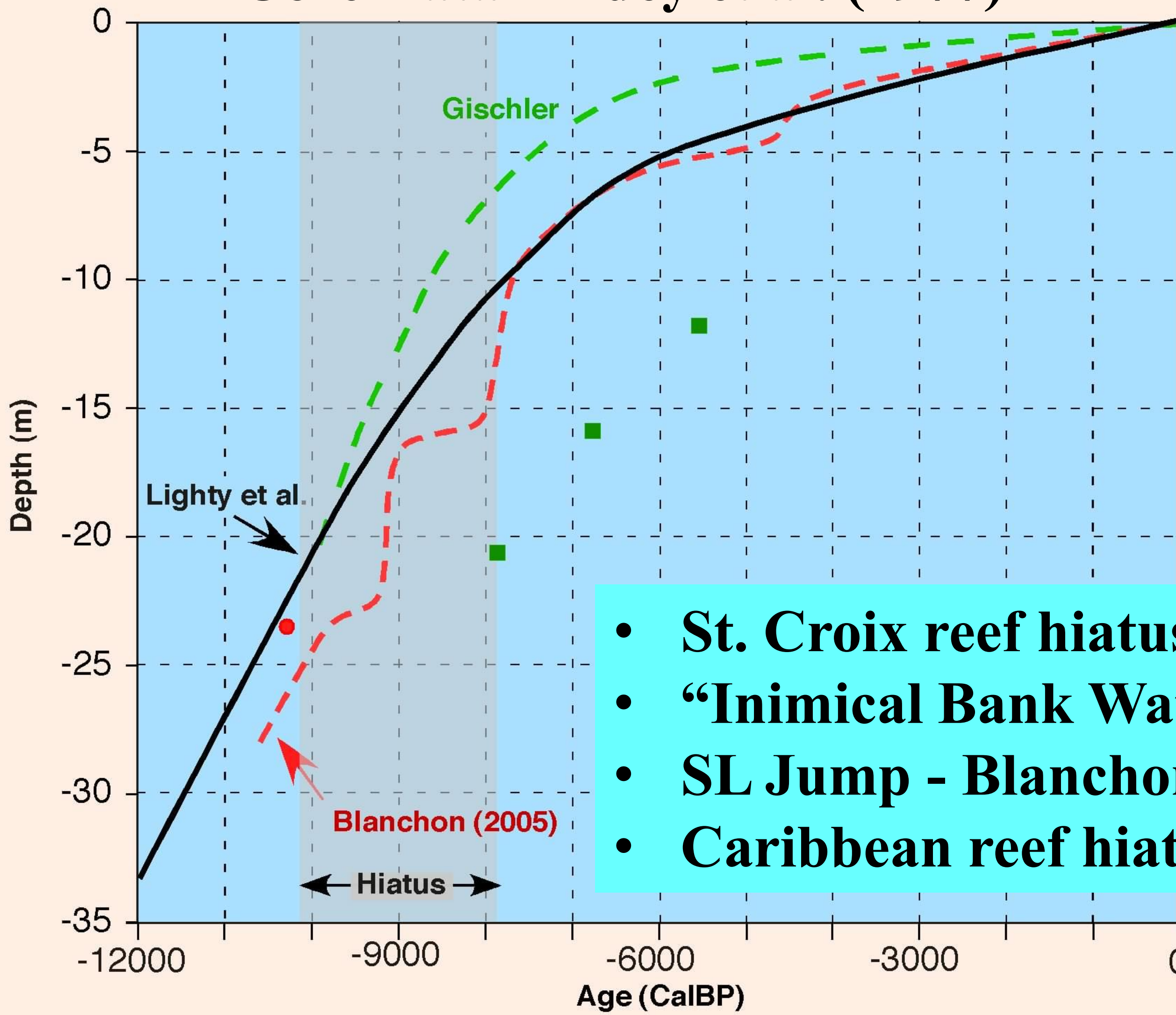



37 cores
Adey et al (1977)



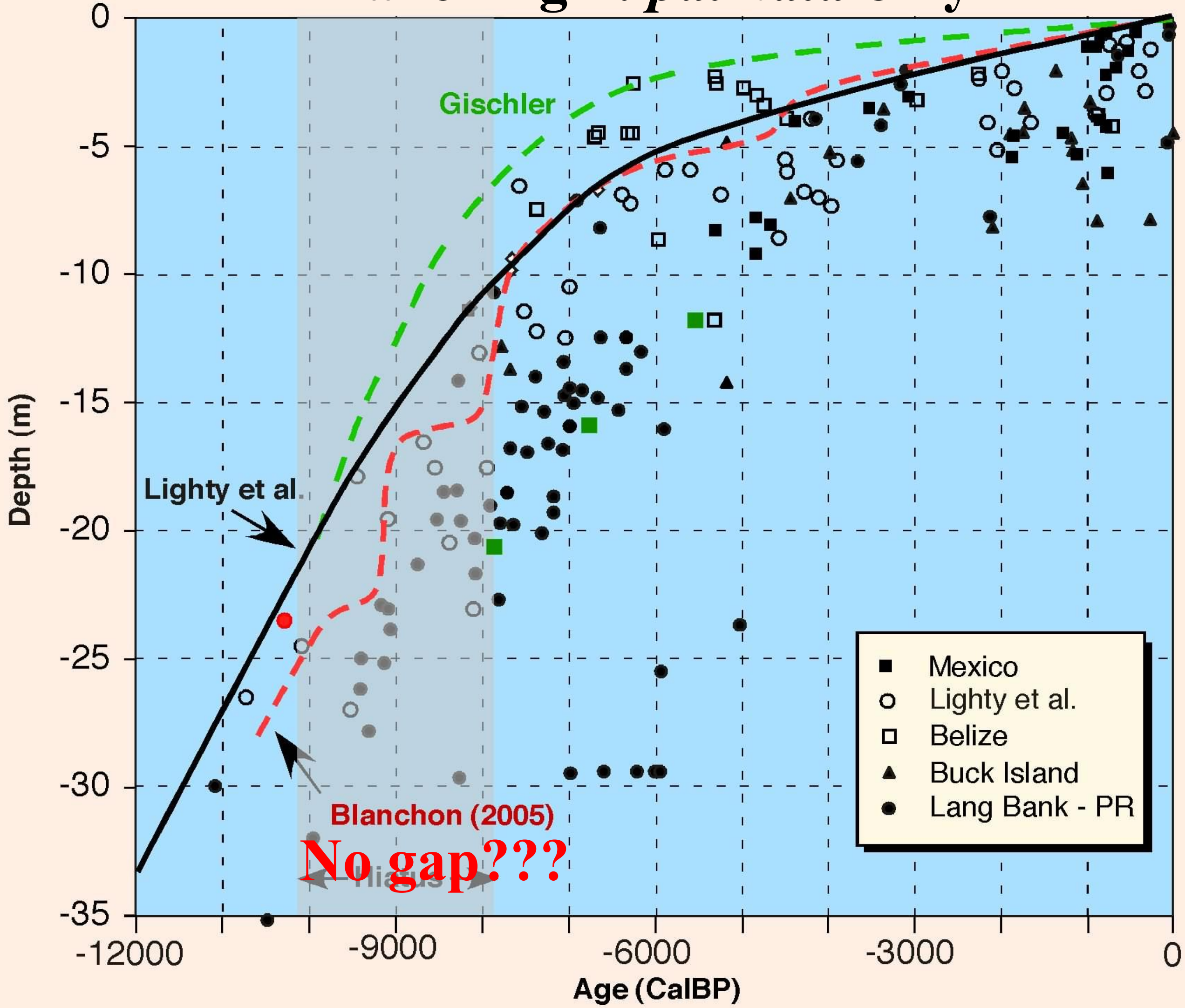

N
La Parguera
10m
20m
ca. 1km to shelf edge (10 cores)
0
Km
3
19 Cores
Atlantic Ocean
La Parguera
Lang
Bank
Caribbean Sea
100 km
Google Earth
Data SIO, NOAA, US Navy, NCA, GFBCO

# Core Data – Adey et al. (1977)




- St. Croix reef hiatus
- "Inimical Bank Waters"
- SL Jump - Blanchon
- Caribbean reef hiatus

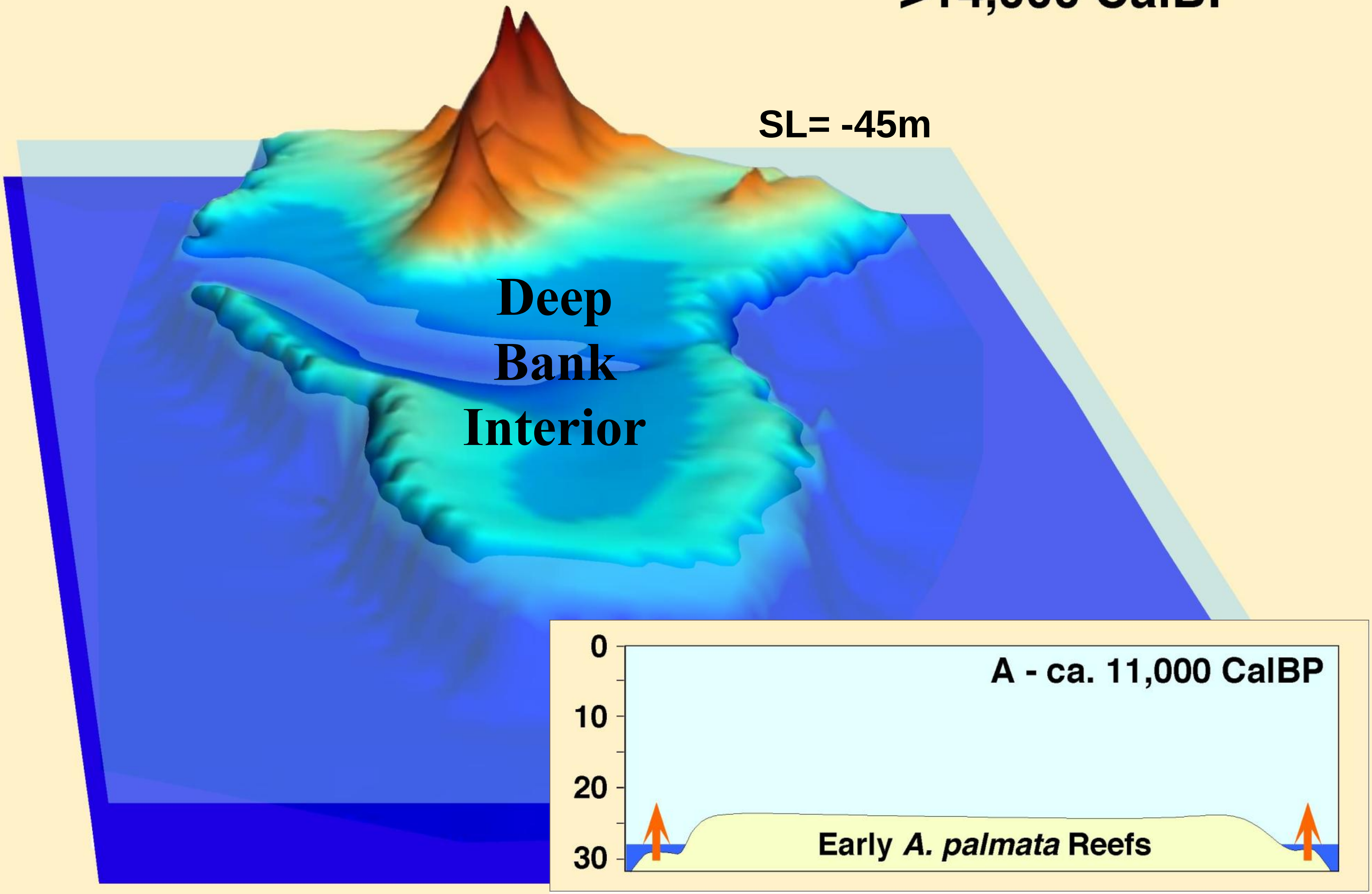
# Branching *A. palmata* only



# If there is no gap…..

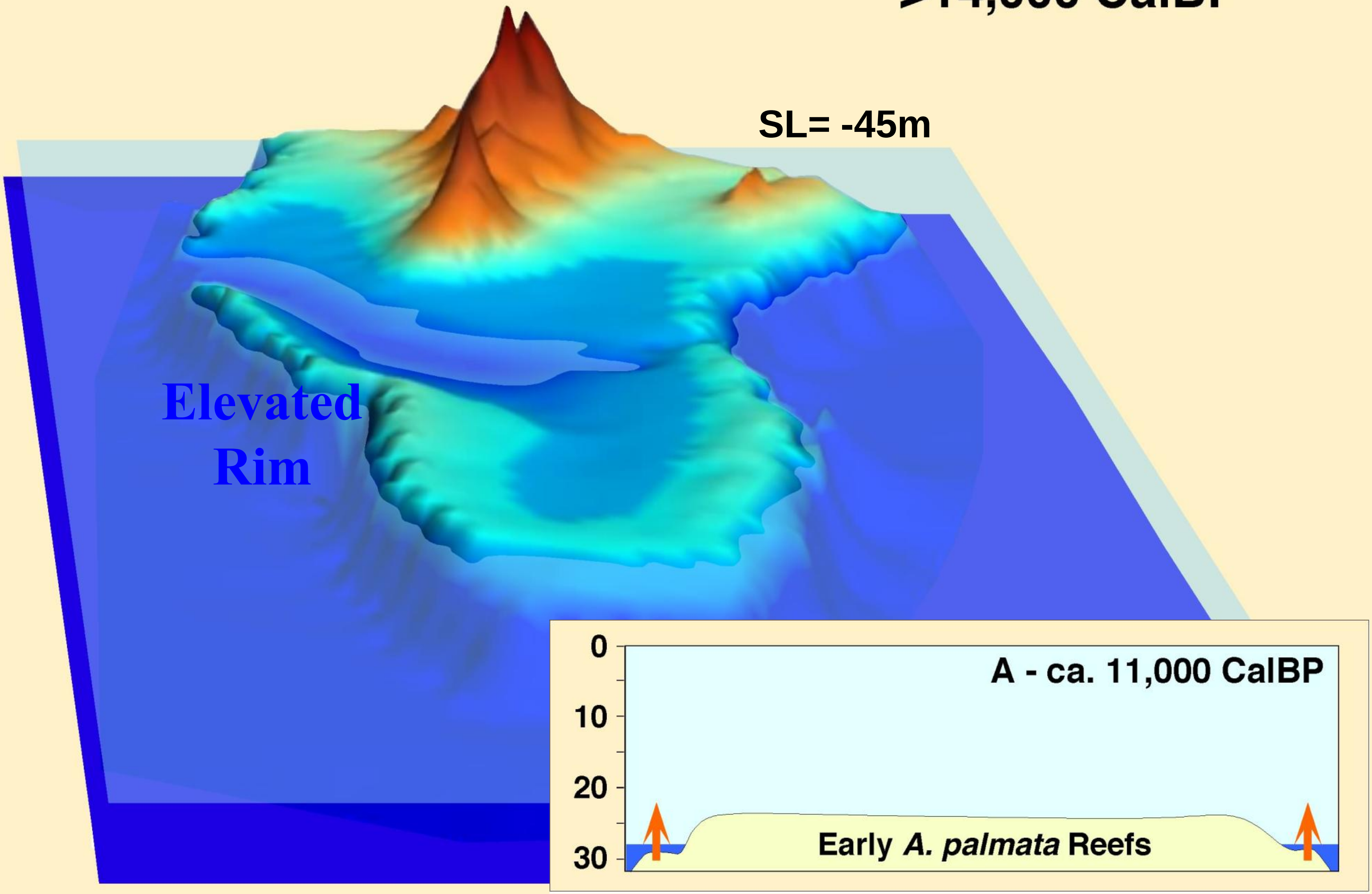
- No need for an explanation
  - IBW
  - Sea-Level Jump
- The reefs still backstepped

>14,000 CalBP

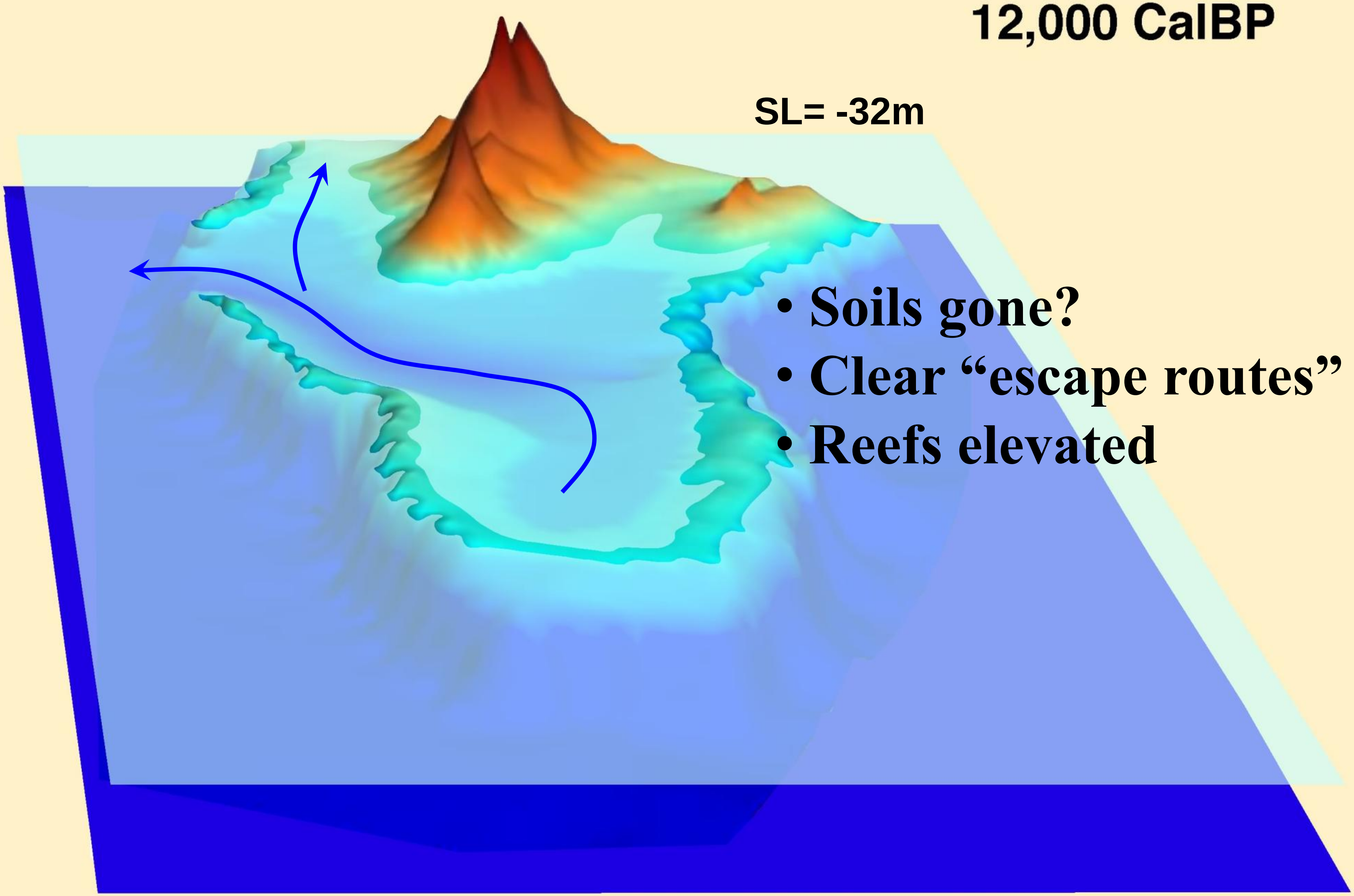


SL= -45m
Deep
Bank
Interior
A - ca. 11,000 CalBP
0
10
20
30
Early *A. palmata* Reefs

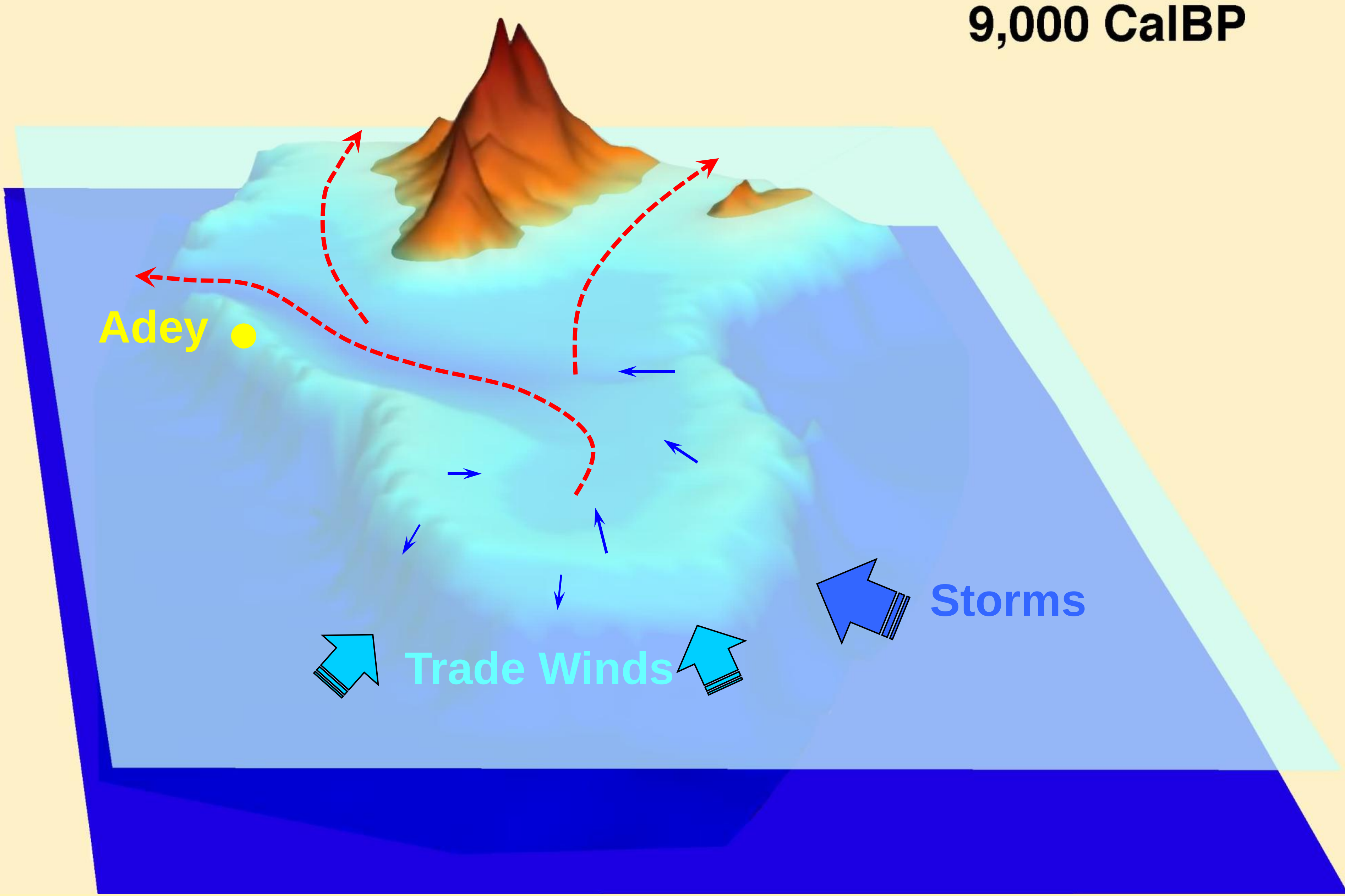
>14,000 CalBP


SL= -45m
Elevated
Rim
0
10
20
30
A - ca. 11,000 CalBP
Early *A. palmata* Reefs

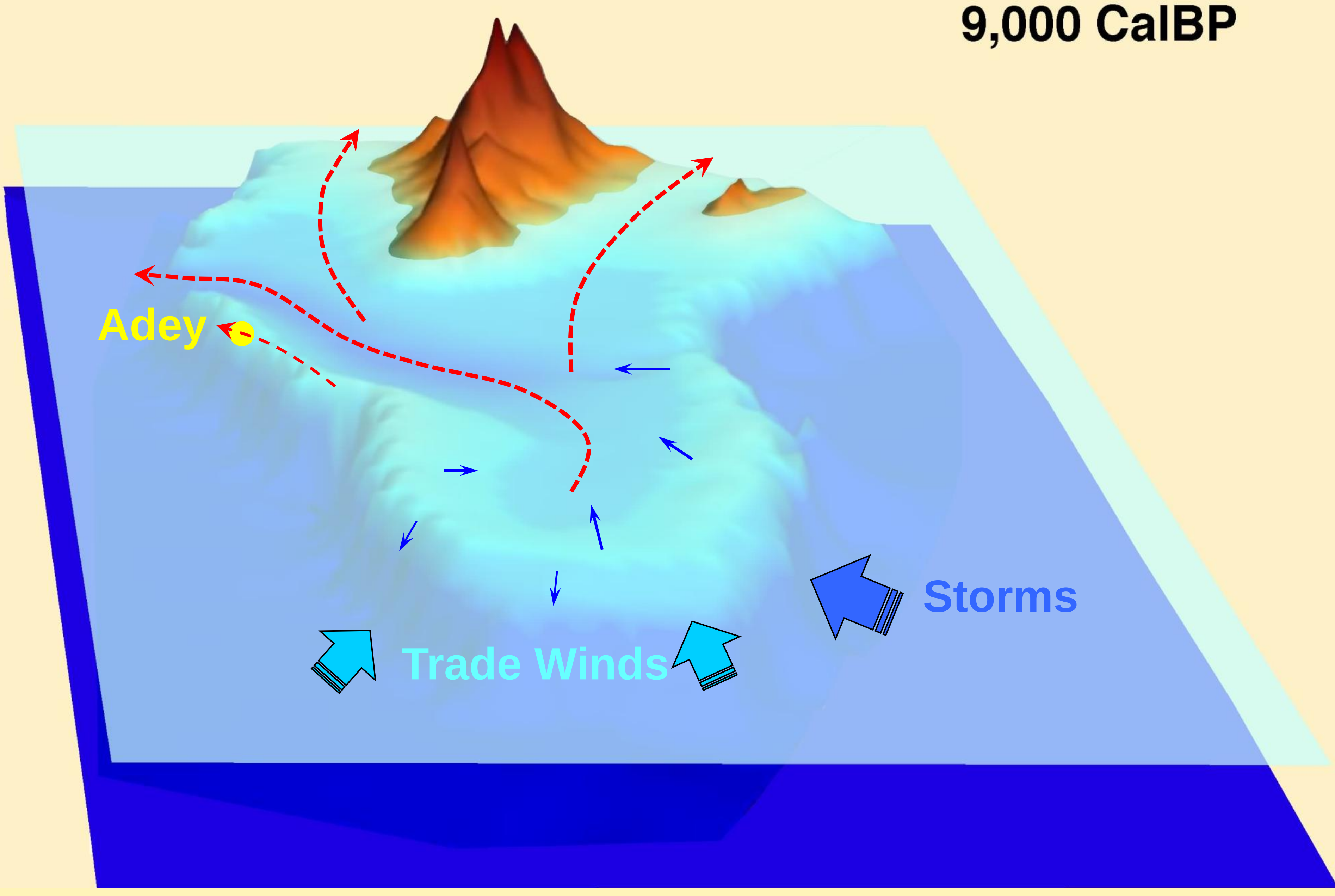
# 12,000 CalBP




- Soils gone?
- Clear “escape routes”
- Reefs elevated



9,000 CalBP
Adey
Storms
Trade Winds

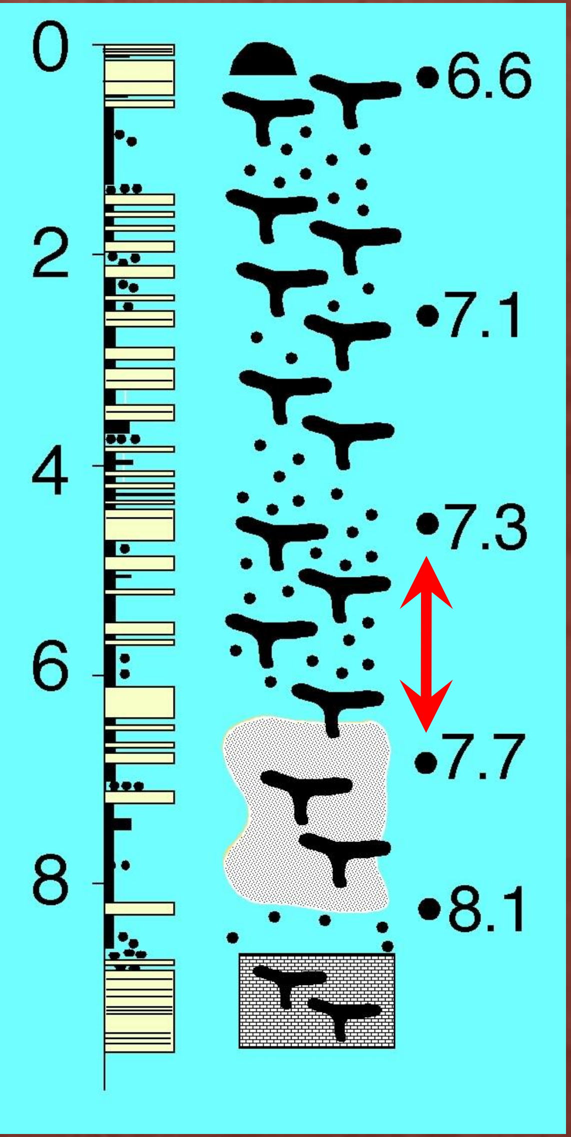


9,000 CalBP
Adey
Storms
Trade Winds

# Questions for today:

- What happened 10,000 year
- How fast do reefs build?
- How does backstepping wor

Accretion = ΔElev/ΔTime



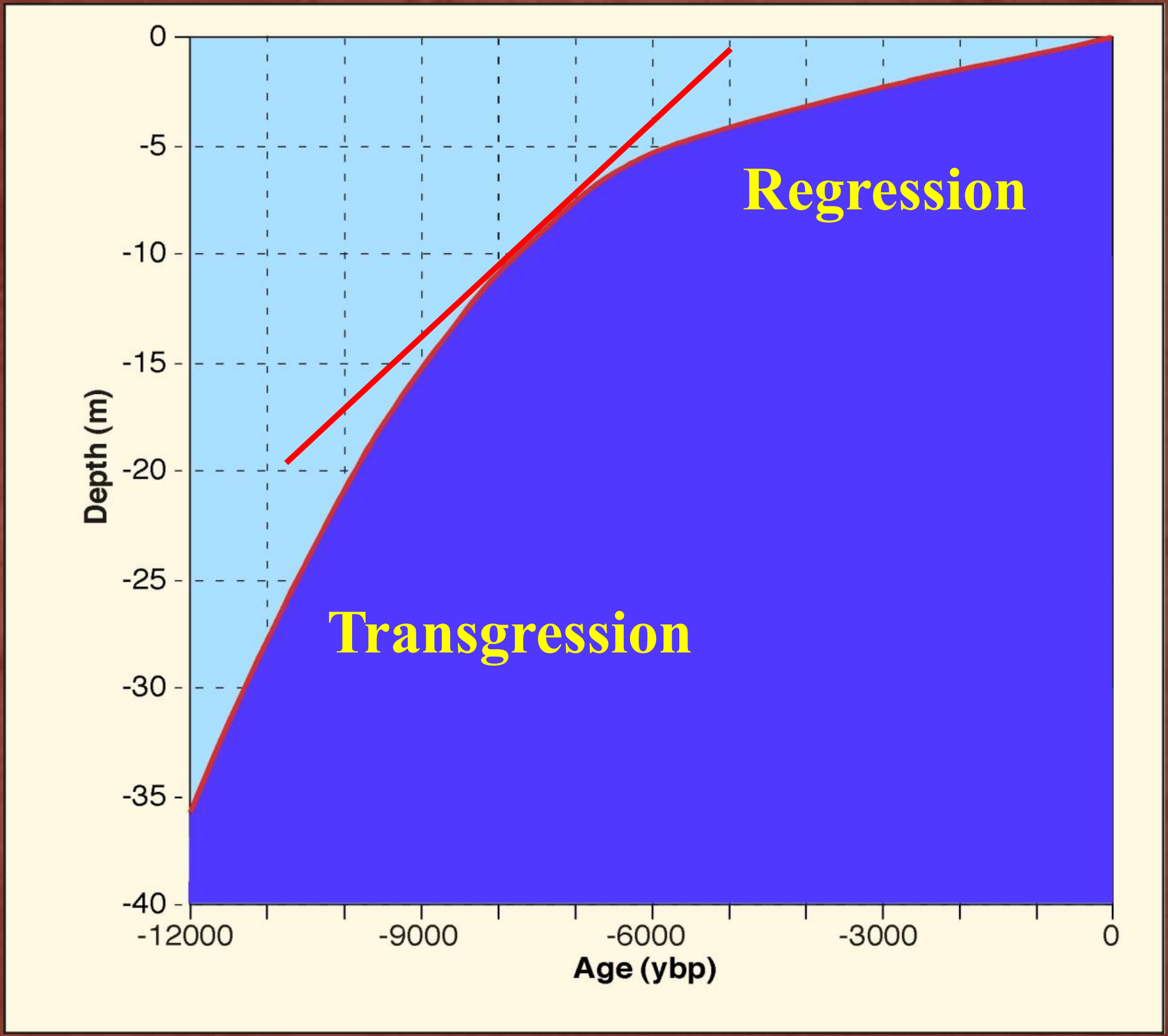

## Core Statistics

- 144 core intervals
- 82 cores
- 16 reefs


# 3.37 m/ky $\pm$ 1.56 m/ky

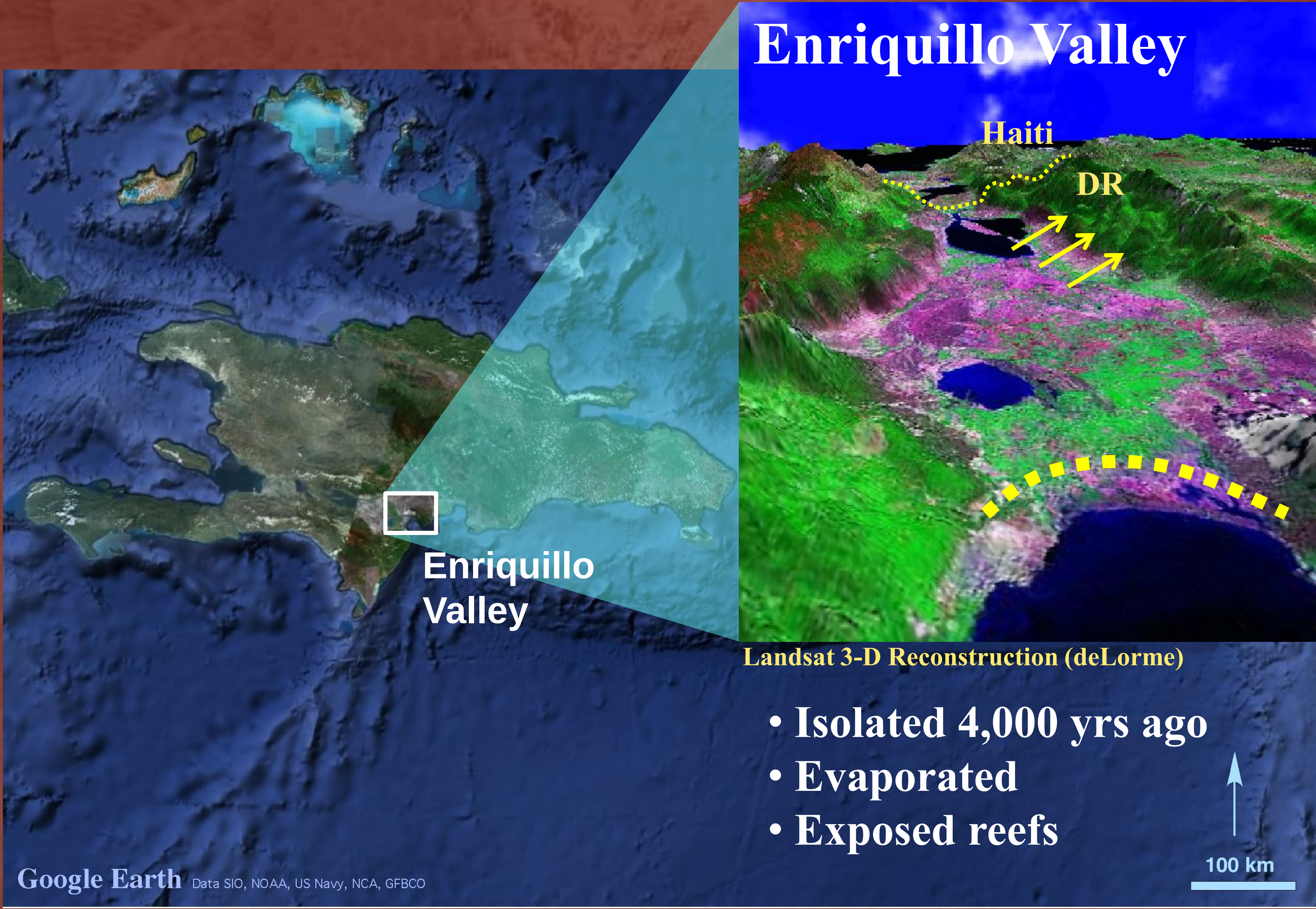
# ≠10-14 m/ky


- **No hiatus @ 10,000 CalBP**
- **Accretion << Max SL Rise**




3.37 m/ky $\pm$ 1.56 m/ky

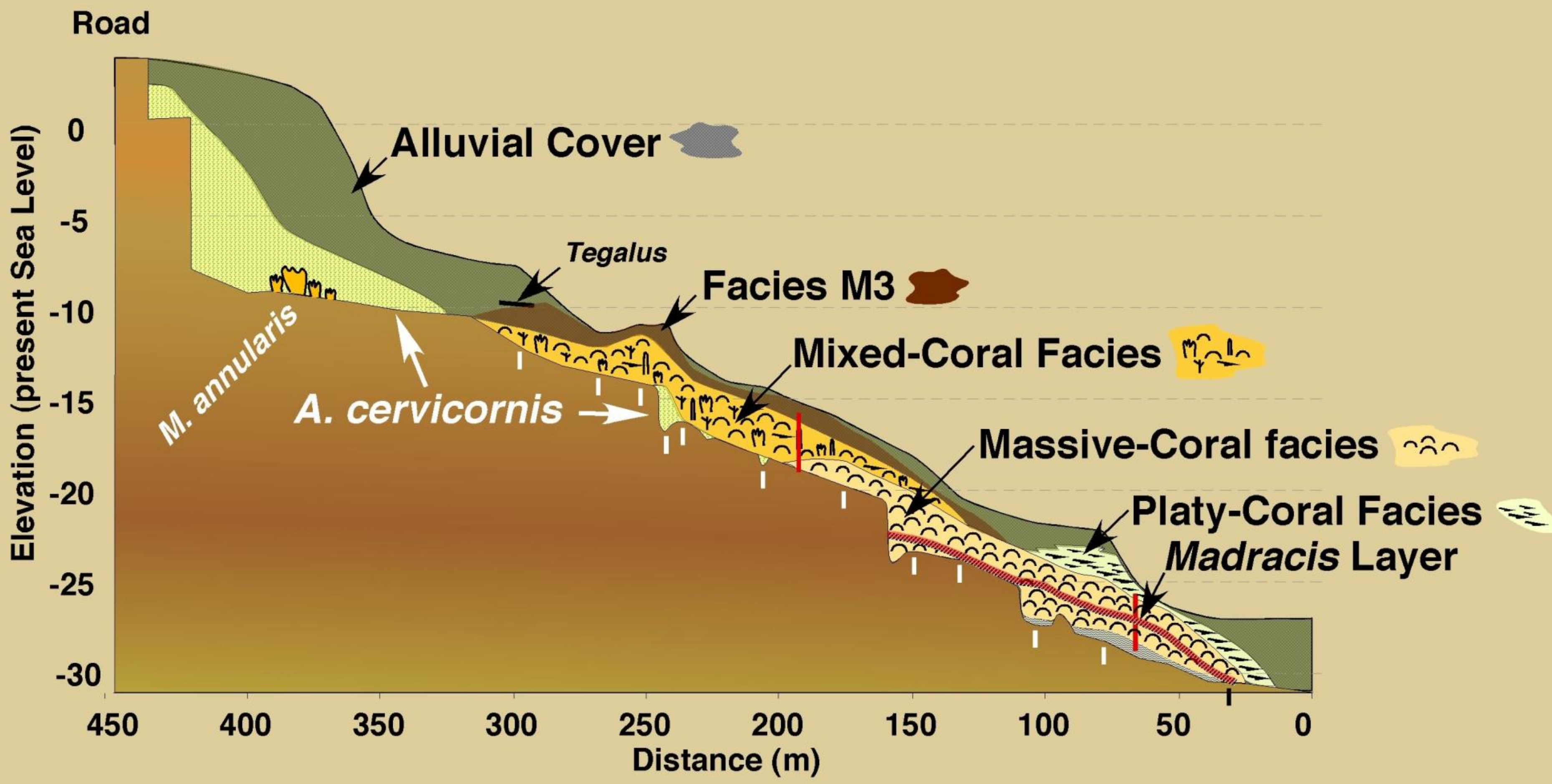
**Based on cores……**



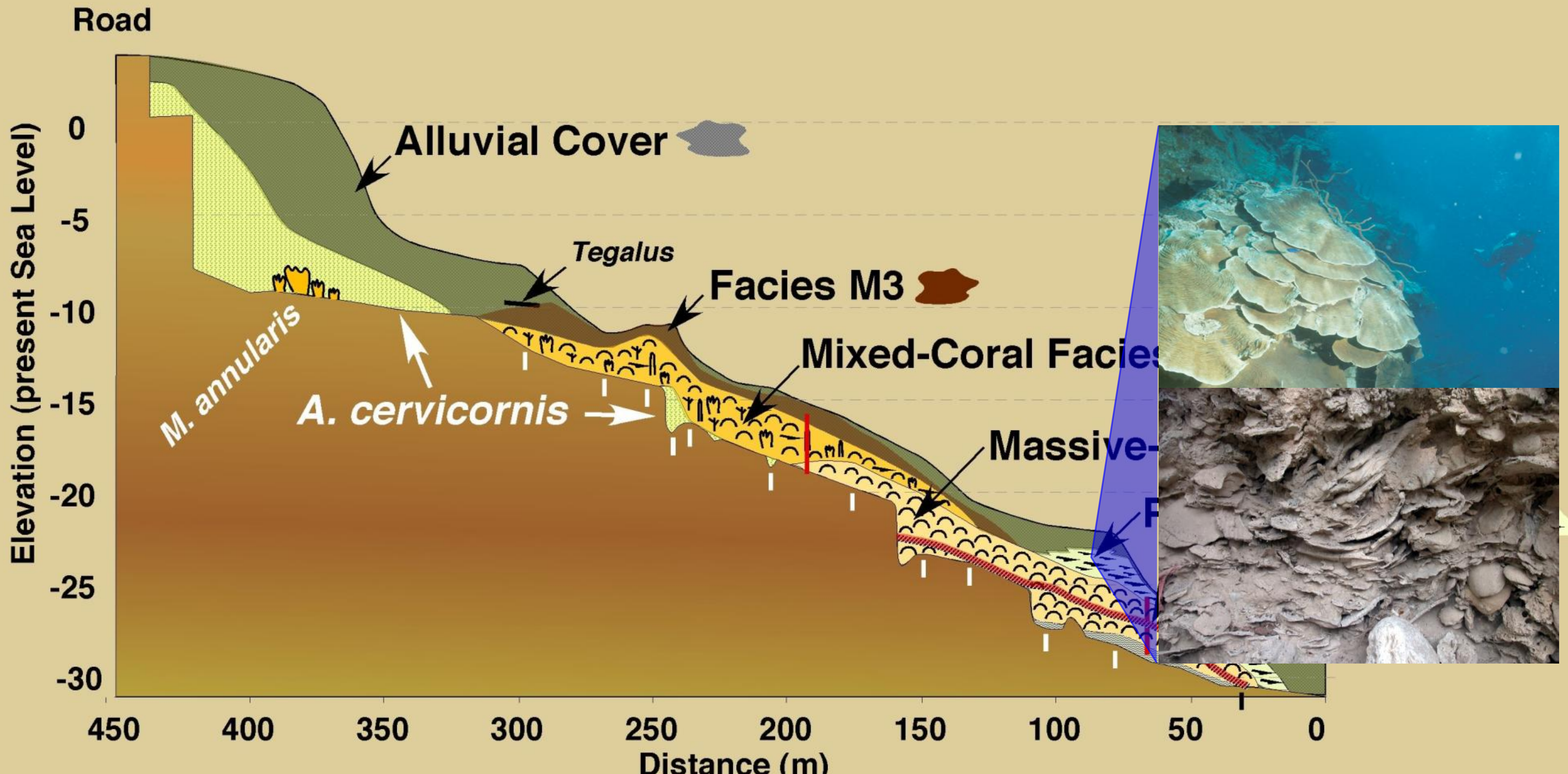

Landsat 3-D Reconstruction (deLorme)

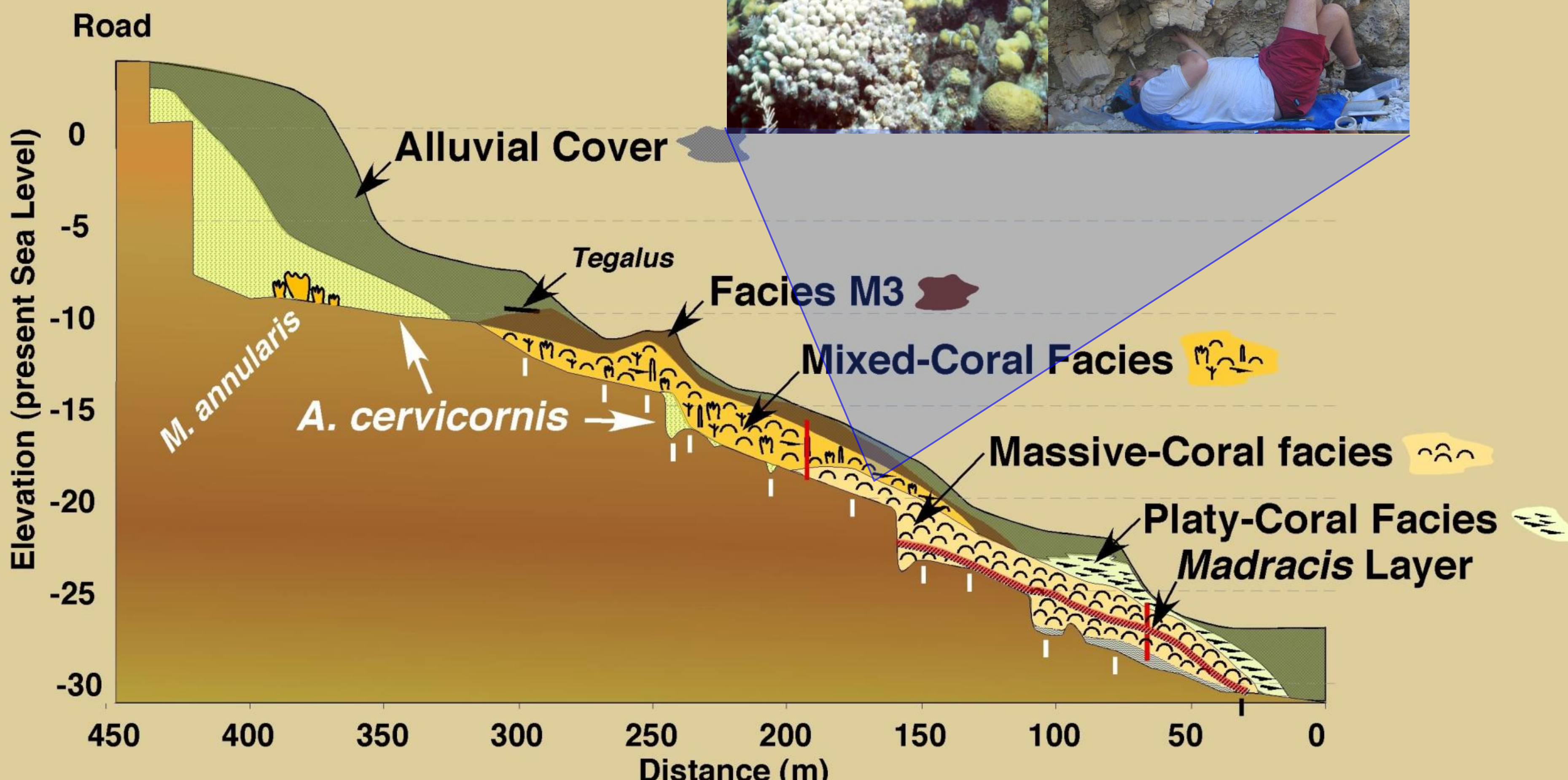
- Isolated 4,000 yrs ago
- Evaporated
- Exposed reefs

# Cañada Honda Facies



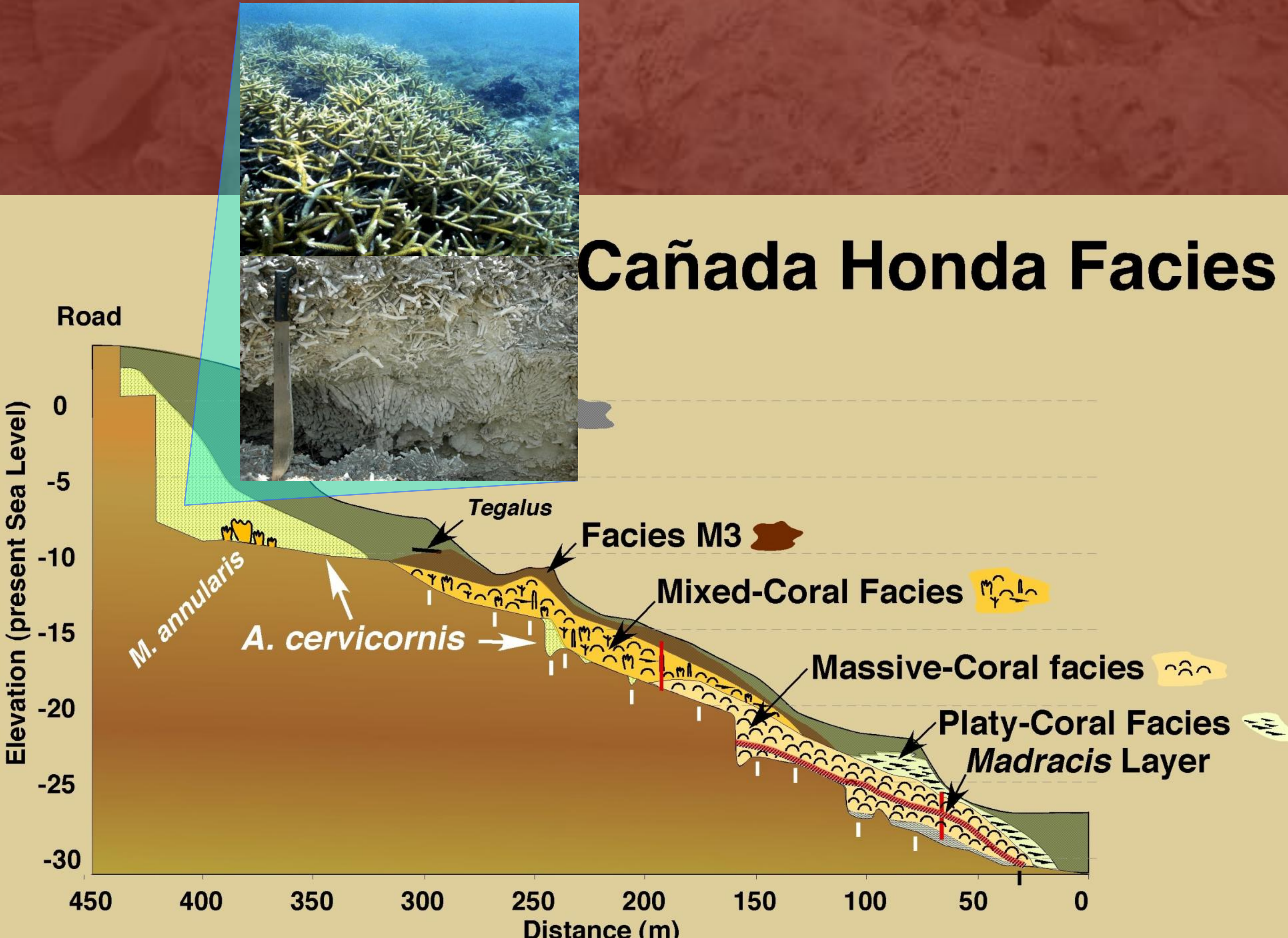
# Cañada Honda Facies





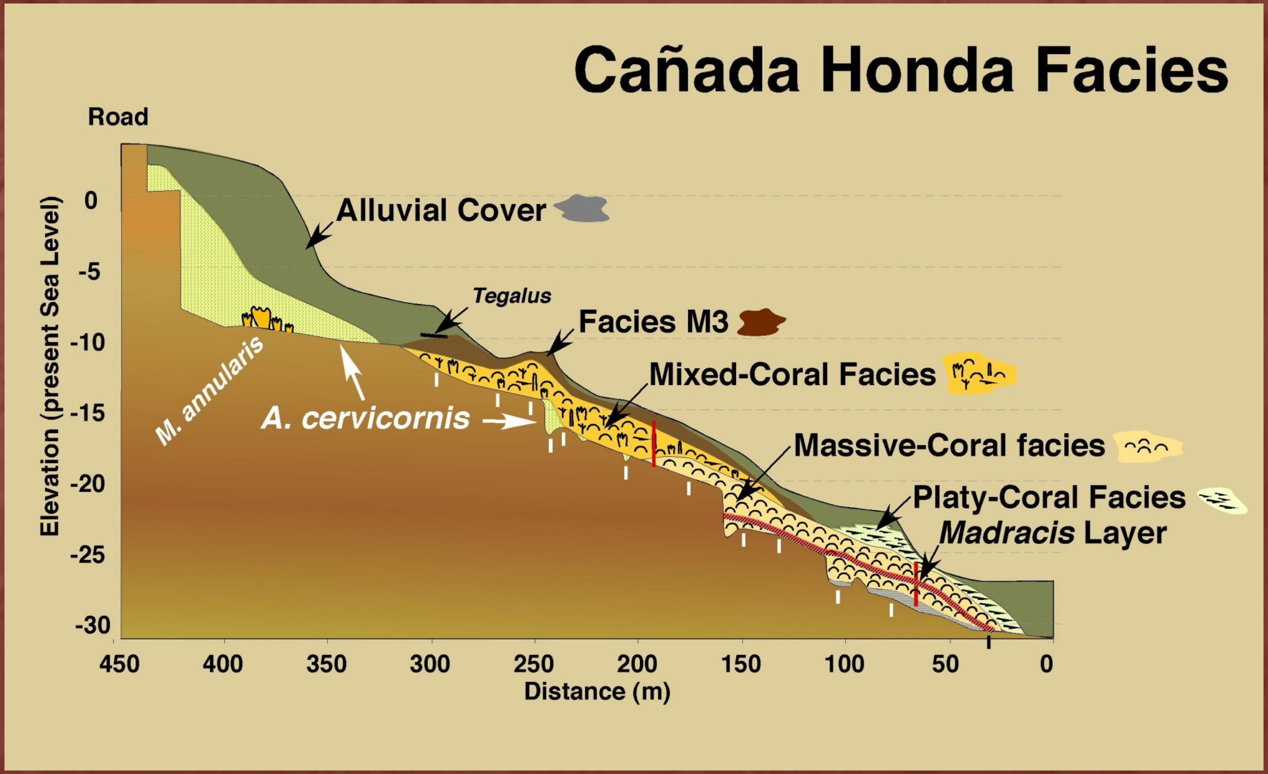
Road
Elevation (present Sea Level)
0
-5
-10
-15
-20
-25
-30
Alluvial Cover
*Tegalus*
Facies M3
Mixed-Coral Facies
*M. annularis*
*A. cervicornis*
Massive-Coral facies
Platy-Coral Facies
*Madracis* Layer
450
400
350
300
250
200
150
100
50
0
Distance (m)

# Cañada Honda Facies

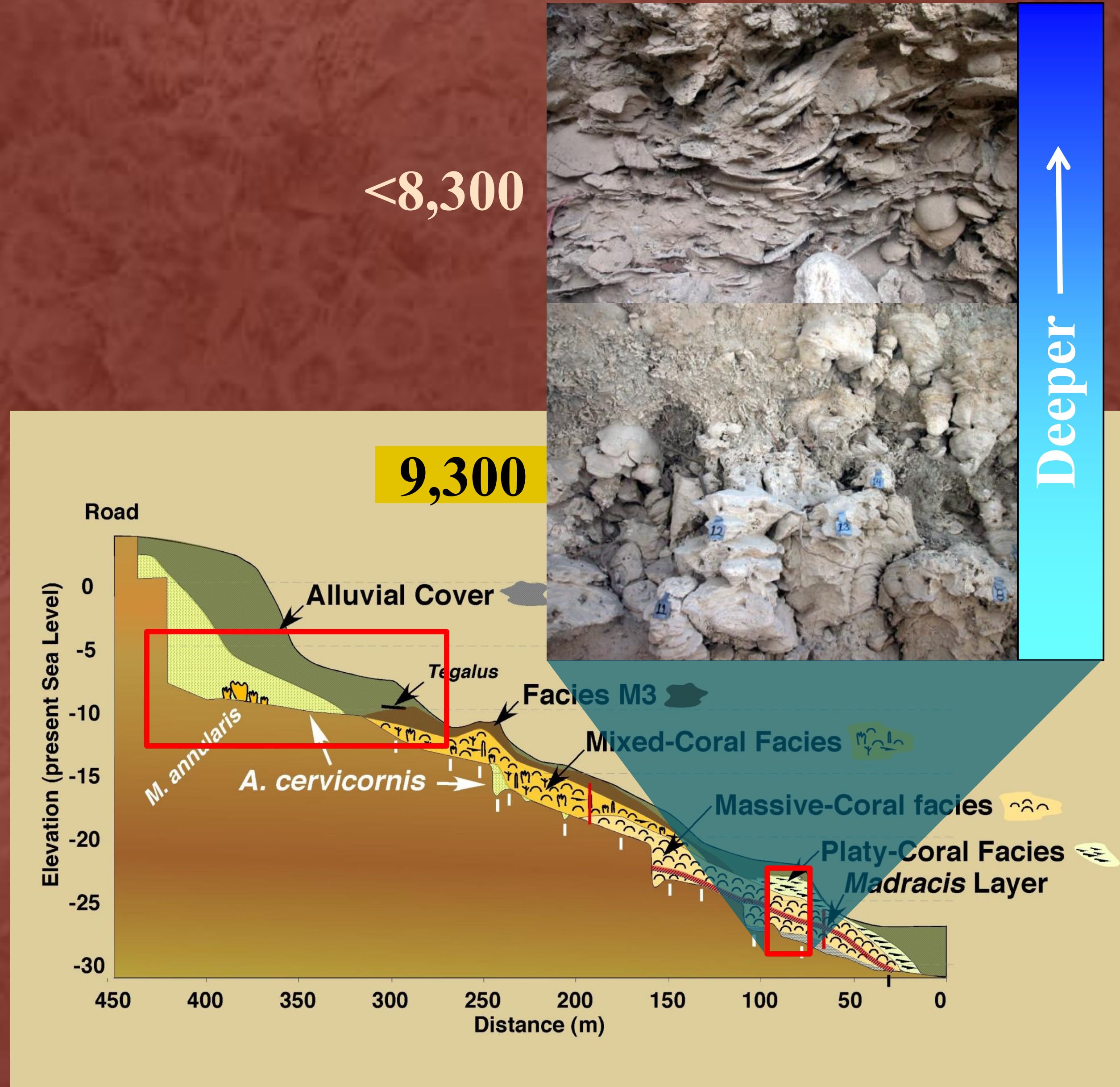


**Shallow**

**Deep**



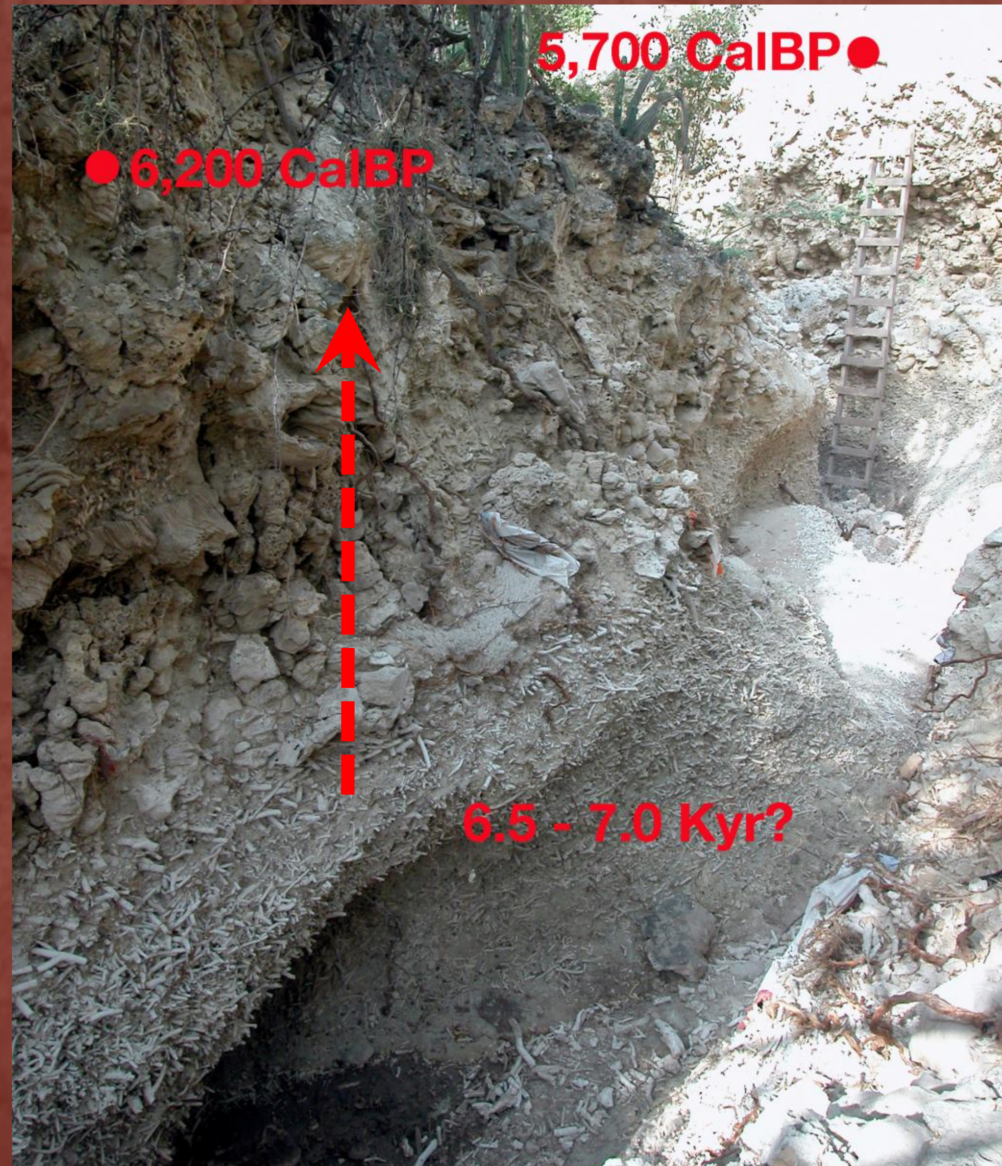
Shallow




Deep

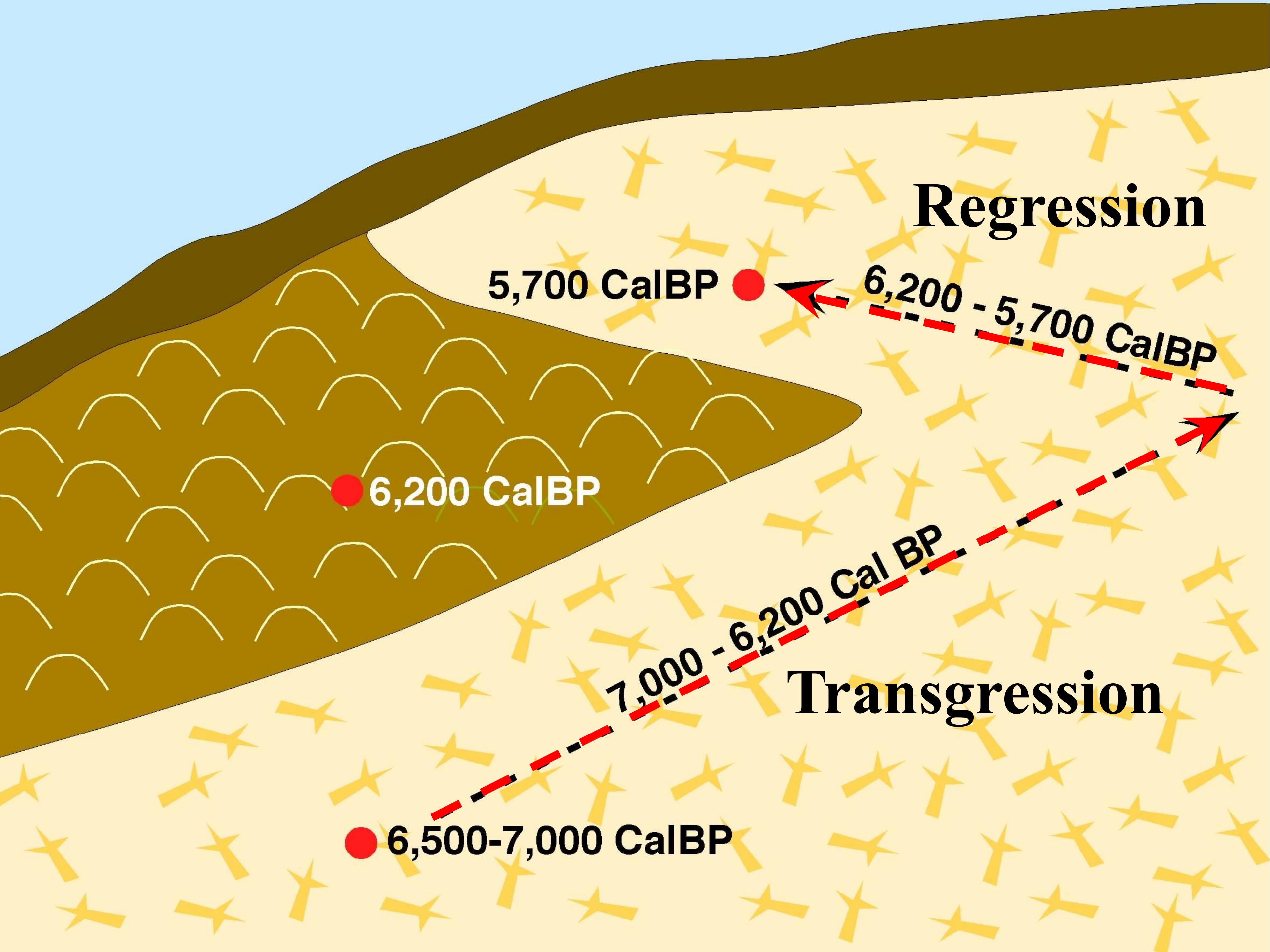
Shallow

Deep



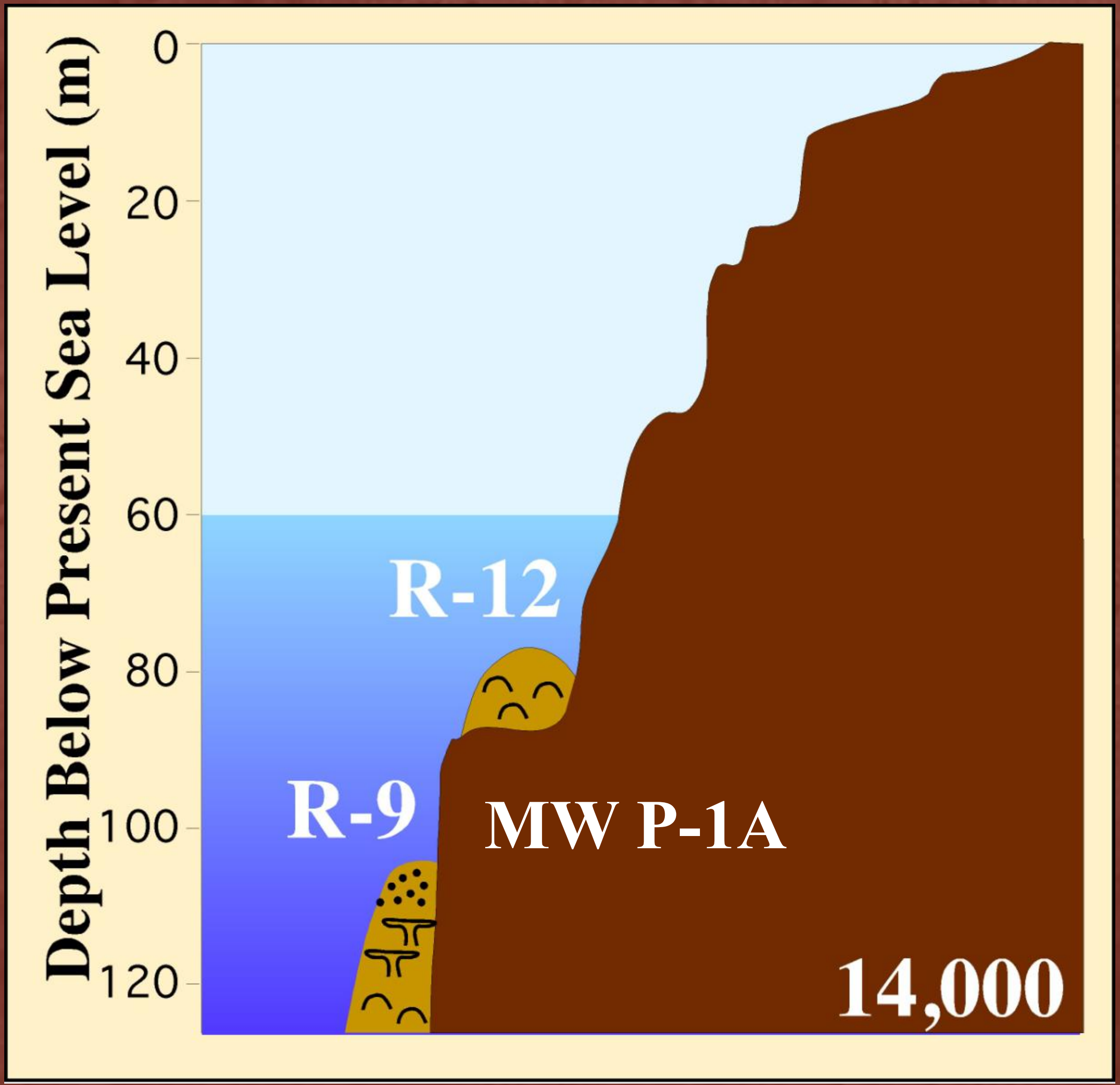
Shallow

Deep



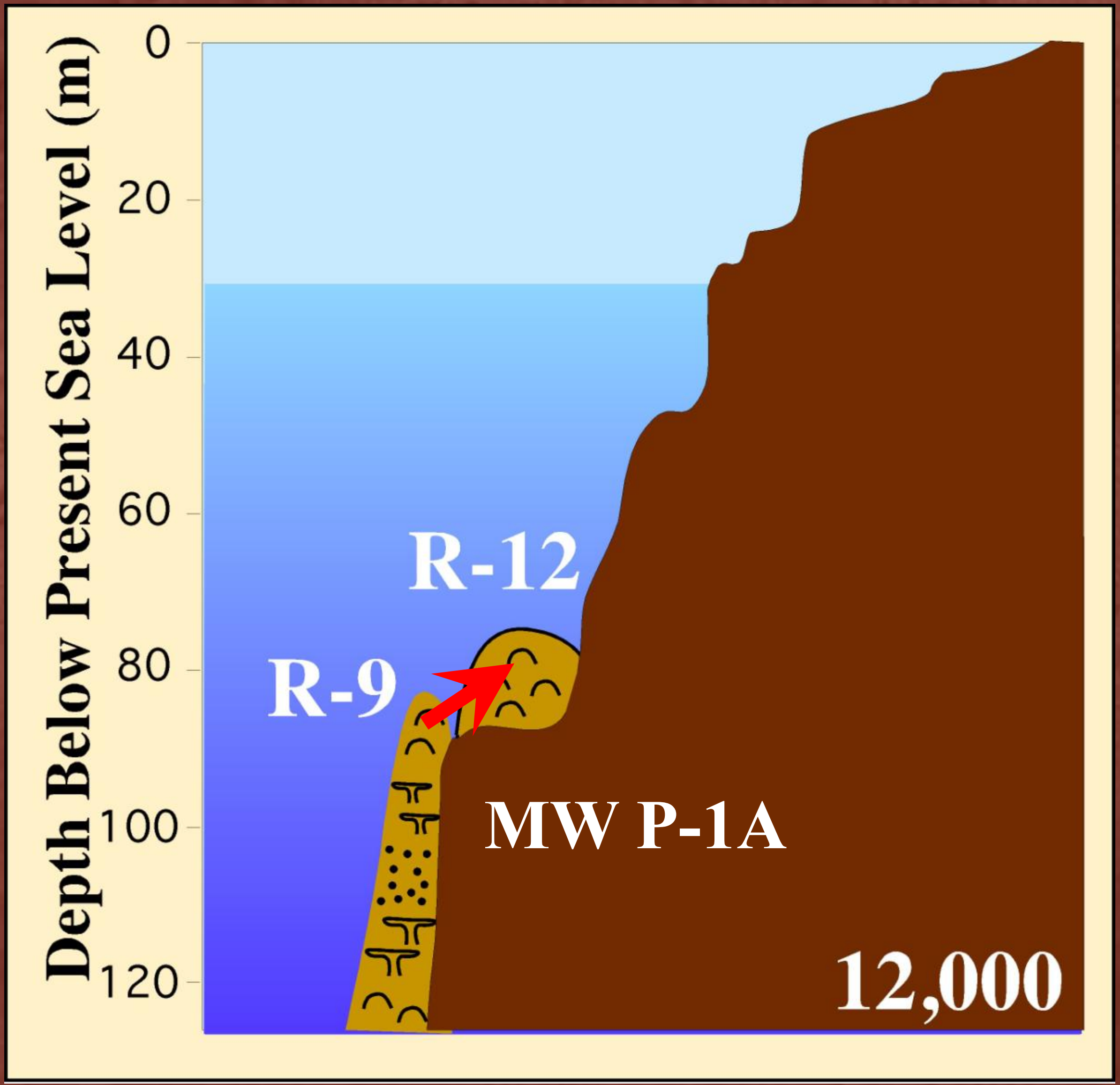
Regression
5,700 CalBP
6,200 - 5,700 CalBP
6,200 CalBP
7,000 - 6,200 Cal BP
Transgression
6,500-7,000 CalBP

# Backstepping on Barbados




Data from Fairbanks (1989)

# Backstepping on Barbados

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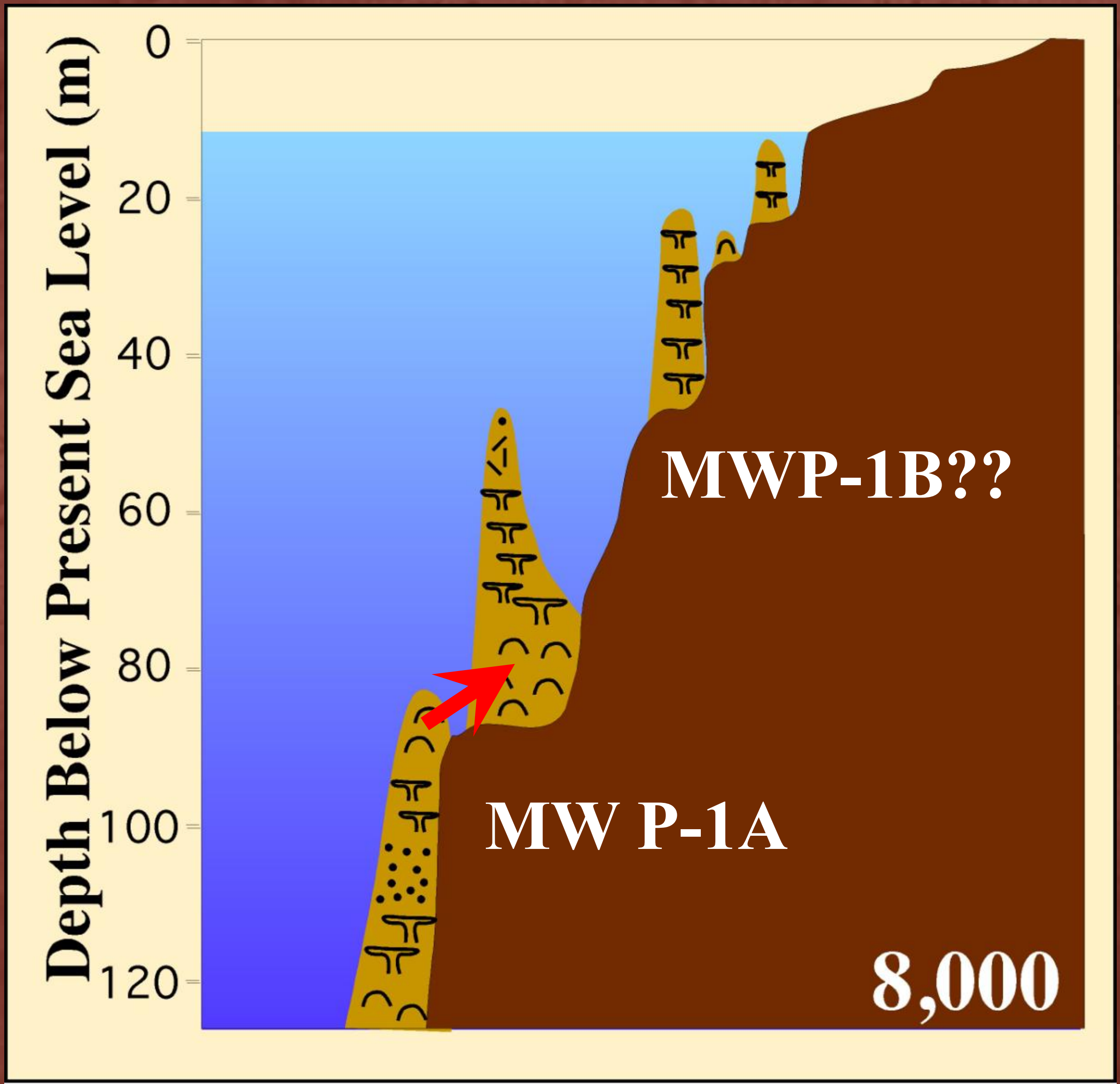


Data from Fairbanks (1989)

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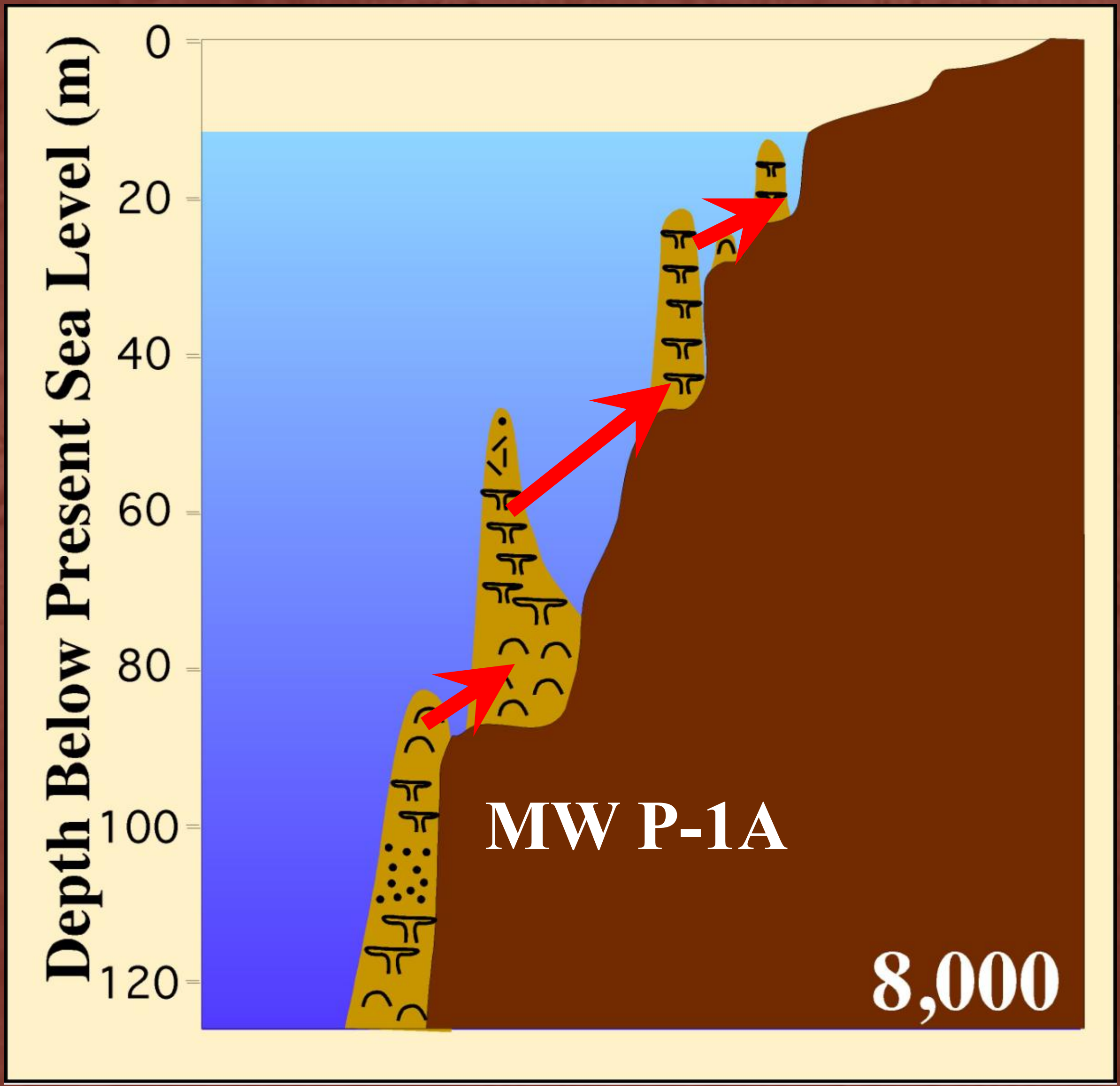
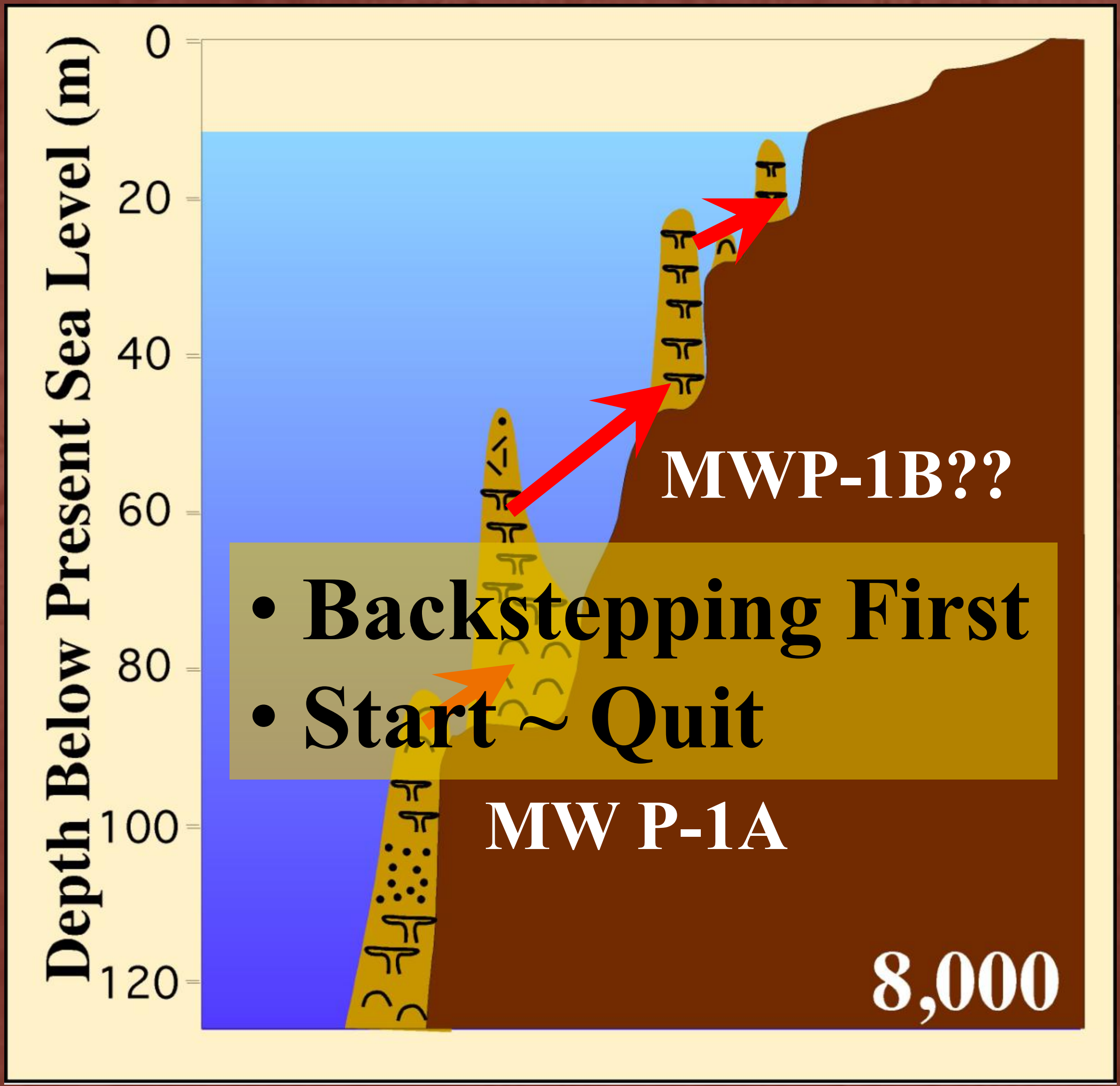
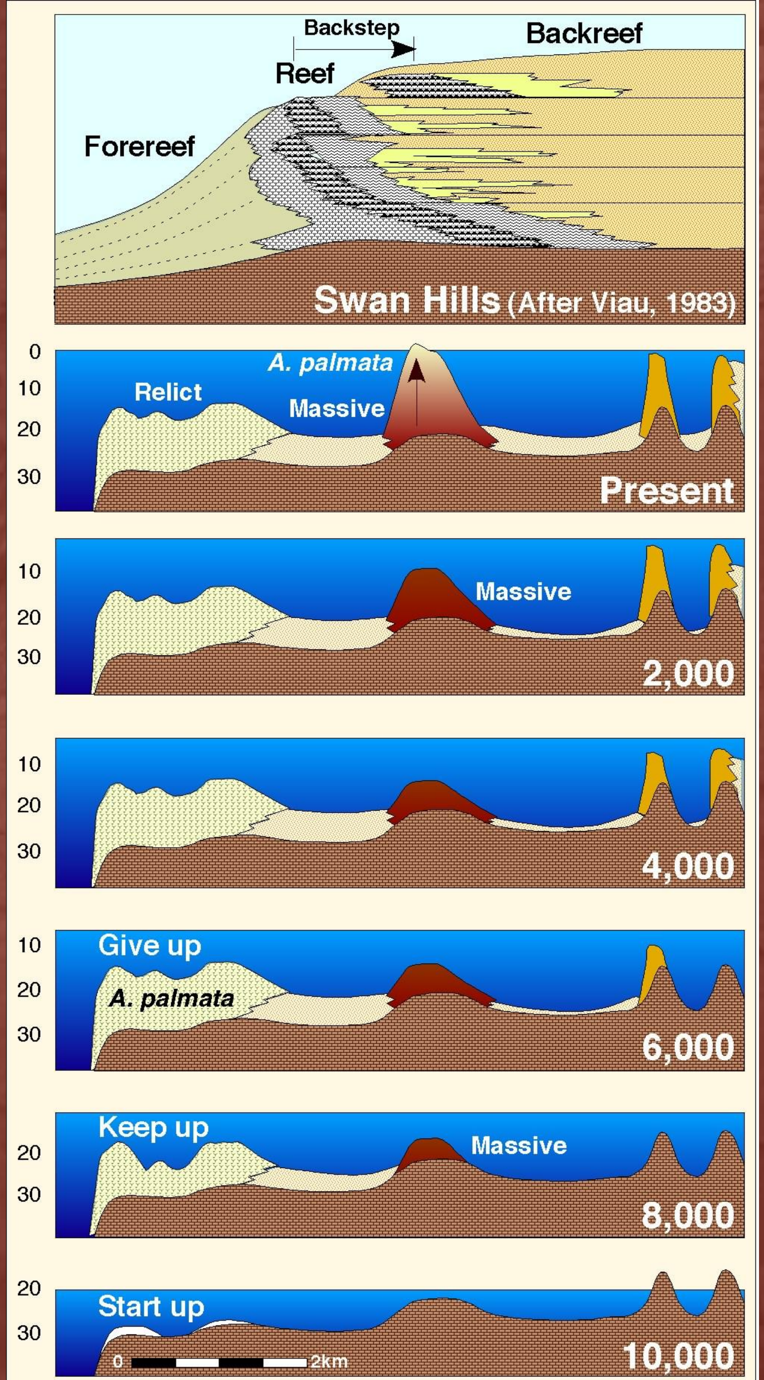



Data from Fairbanks (1989)

# Backstepping on Barbados




Data from Fairbanks (1989)



Backstep
Backreef
Reef
Forereef
Swan Hills (After Viau, 1983)
0
10
20
30
A. palmata
Relict
Massive
Present
10
20
30
Massive
2,000
10
20
30
4,000
10
20
30
Give up
A. palmata
6,000
20
30
Keep up
Massive
8,000
20
30
Start up
0
2km
10,000

# CONCLUSIONS:

- Sea level can jump
- Water can get dirty
- Not on Lang Bank
- No hiatus to explain (local, etc.)
- Caribbean reef accretion ~ 3-5 m/ky
- SL = 10 m/ky & can leave reefs behind
- Caribbean model “flawed”
- Backstepping can occur “normally”

# Looking Forward……..