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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The “Rules” of Reef Geometry

Accretion vs Sea Level

Production + Transport = GE Sea Level + “Tectonics”

BACKSTEPPING = abandonment → shift
It is generally tied to dramatic change
Adey et al. (1977)
The Lang Bank Story

After Adey et al. (1977)

D - Today

C - ca. 8,000 CalBP

Water Clears - Too Deep

B - ca. 10,000 CalBP

Sediment-Laden Water

Bank Top Floods

A - ca. 11,000 CalBP

~10m/ky

Early A. palmata Reefs

After Adey et al. (1977)
The Lang Bank Story

After Adey et al. (1977)
The Lang Bank Story

After Adey et al. (1977)
The Lang Bank Story

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The Lang Bank Story

After Adey et al. (1977)

Backstepping (8,000 – 6,000 CalBP)
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)
Too Little Light

A sudden jump....
“Shot in the backs by their own lagoons?”

A.C. Neumann
Since 1997....
Since 1997…

Adey et al (1977)

37 cores
Core Data – Adey et al. (1977)

- St. Croix reef hiatus
- “Inimical Bank Waters”
- SL Jump - Blanchon
- Caribbean reef hiatus
Core Data

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

Branching *A. palmata* only

No gap???
If there is no gap.....

• No need for an explanation
  • IBW
  • Sea-Level Jump
• The reefs still backstepped
- Soils gone?
- Clear “escape routes”
- Reefs elevated
Trade Winds

Storms

Adey

9,000 CalBP
Questions for today:

• What happened 10,000 years ago?
• How fast do reefs build?
• How does backstepping work?

Accretion = ΔElev/ΔTime
Core Statistics

- 144 core intervals
- 82 cores
- 16 reefs
3.37 m/ky ± 1.56 m/ky ≠ 10-14 m/ky
• No hiatus @ 10,000 CalBP
• Accretion << Max SL Rise
3.37 m/ky ± 1.56 m/ky

Based on cores…….
Enriquillo Valley

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

Landsat 3-D Reconstruction (deLorme)
Shallow

Deep
Shallow

<8,300

9,300

Deeper

Deep
Shallow

Deep

5,700 CalBP

6,200 CalBP

6.5 - 7.0 Kyr?
Backstepping on Barbados

Data from Fairbanks (1989)
Backstepping on Barbados

Data from Fairbanks (1989)
Backstepping on Barbados

Data from Fairbanks (1989)
Backstepping on Barbados

Data from Fairbanks (1989)

Depth Below Present Sea Level (m)

MW P-1A

8,000
Backstepping on Barbados

Data from Fairbanks (1989)

• Backstepping First
• Start ~ Quit

MWP-1B??

MW P-1A

8,000
CONCLUSIONS:

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