Morphometric Comparison of the Miami Oolite and Modern High-Energy Sand Bodies of Great Bahama Bank*

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Abstract

Continued interest in modern and outcrop analogs for carbonate sand reservoirs is warranted based on the substantial number of these types of reservoirs. The spatial variability of depositional environments and early diagenetic overprint that potentially creates reservoir heterogeneity within a fossilized carbonate sand system can be observed in outcrops of the oolitic facies of the Pleistocene Miami Limestone. Particularly informative are bare-earth airborne LiDAR (Light Detection And Ranging) data acquired over the breadth of the deposit to create more accurate elevation maps for flood assessment. We use the LiDAR to interrogate bar and channel patterns of the Miami oolite and compare results with those from our previous studies of modern counterparts on Great Bahama Bank. The Miami oolite was deposited as mainly marine sand bars (or shoals), tidal channels, and a barrier bar during the last interglacial highstand – Marine Isotope Stage 5e - when sea level was ~7 m higher than today. The oolitic facies is a wedge-shaped unit reaching its maximum thickness in the barrier bar along the seaward edge of the deposit, whereas a widespread platform interior bryozoan-rich facies occurs to the west. The spatial dimensions of the Miami oolite are comparable to modern ooid shoal systems; the bar and channel portion, 50 km long and 6 km wide, consists of tidal bars and numerous tidal channels. Within the sand body, tidal bars cover approximately 120 km^2, tidal channels about 50 km^2, the barrier bar 20 km^2, and the remainder of the total area is mainly a back-barrier channel immediately behind the barrier bar. The dip and strike extents, as well as shoal morphology, of the Miami oolite and modern Exumas Cays sand body, are similar. The shoals from both display similar diversity in shape, whereas the modern shoals of the Schooner Cays and Tongue of the Ocean adopt a much broader span of shapes. These results confirm that in terms of shoal morphology, the Exumas Cays offers the best analogue to the Miami oolite. Channel patterns show the cumulative lengths of the channels of the Exumas Cays and Miami

oolite are conspicuously short (198 km and 229 km, respectively) and these two sites also have the fewest channels (62 and 43). Channels in the southern reaches of the outcrop belt have low offset angles to the platform margin, reflecting either the N-S drainage and a karst origin or depositional origin related to the barrier bar, which fronts the deposit.

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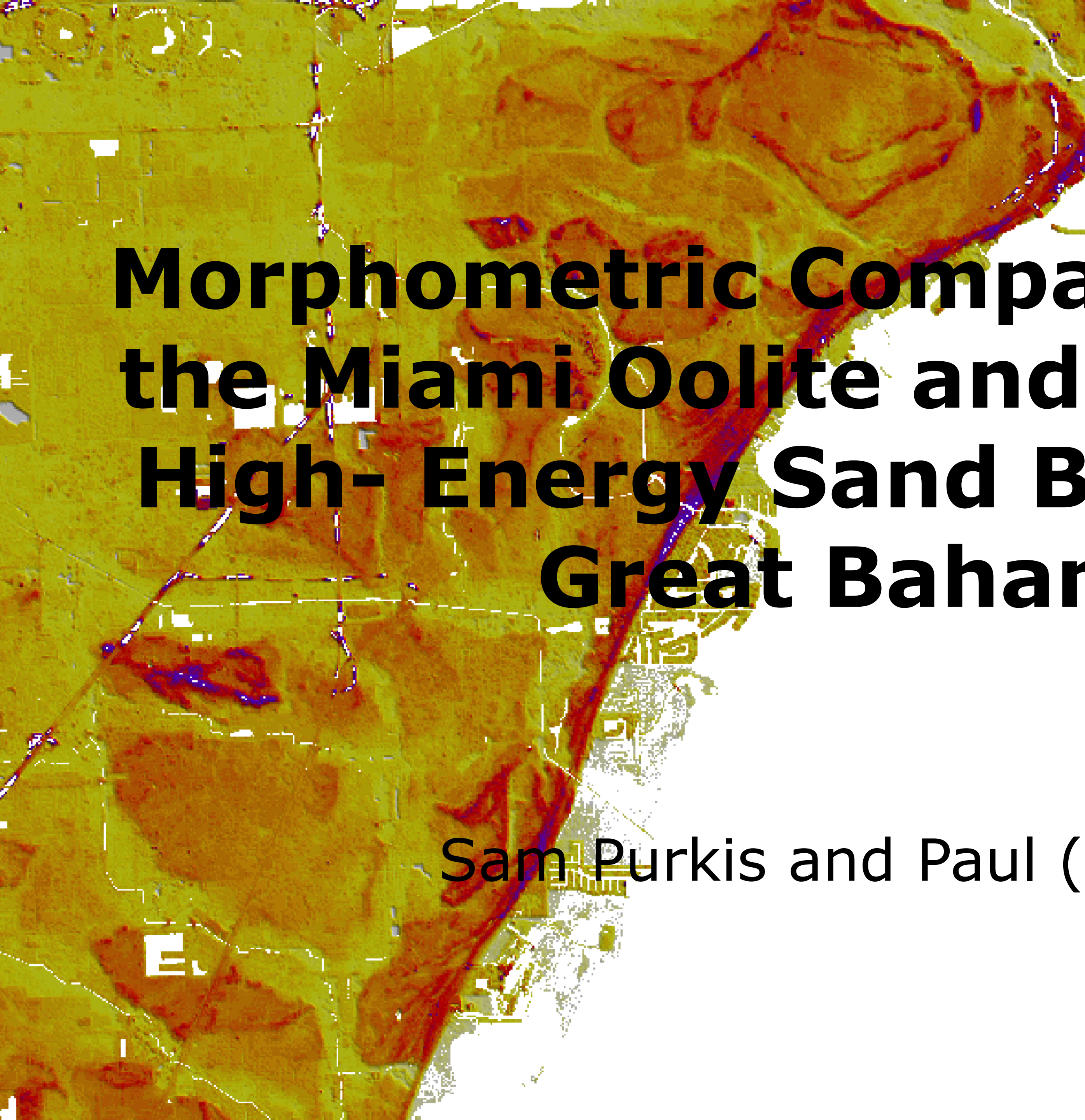

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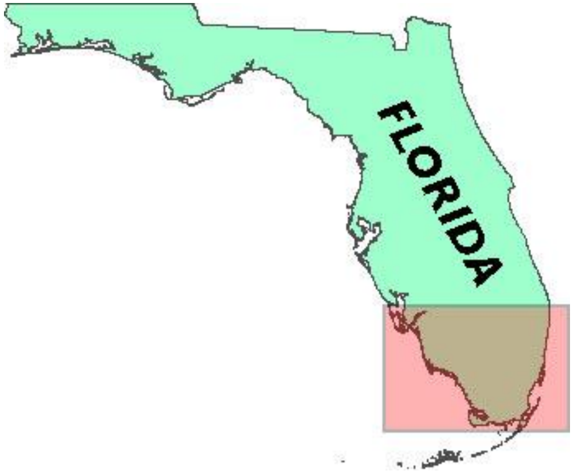
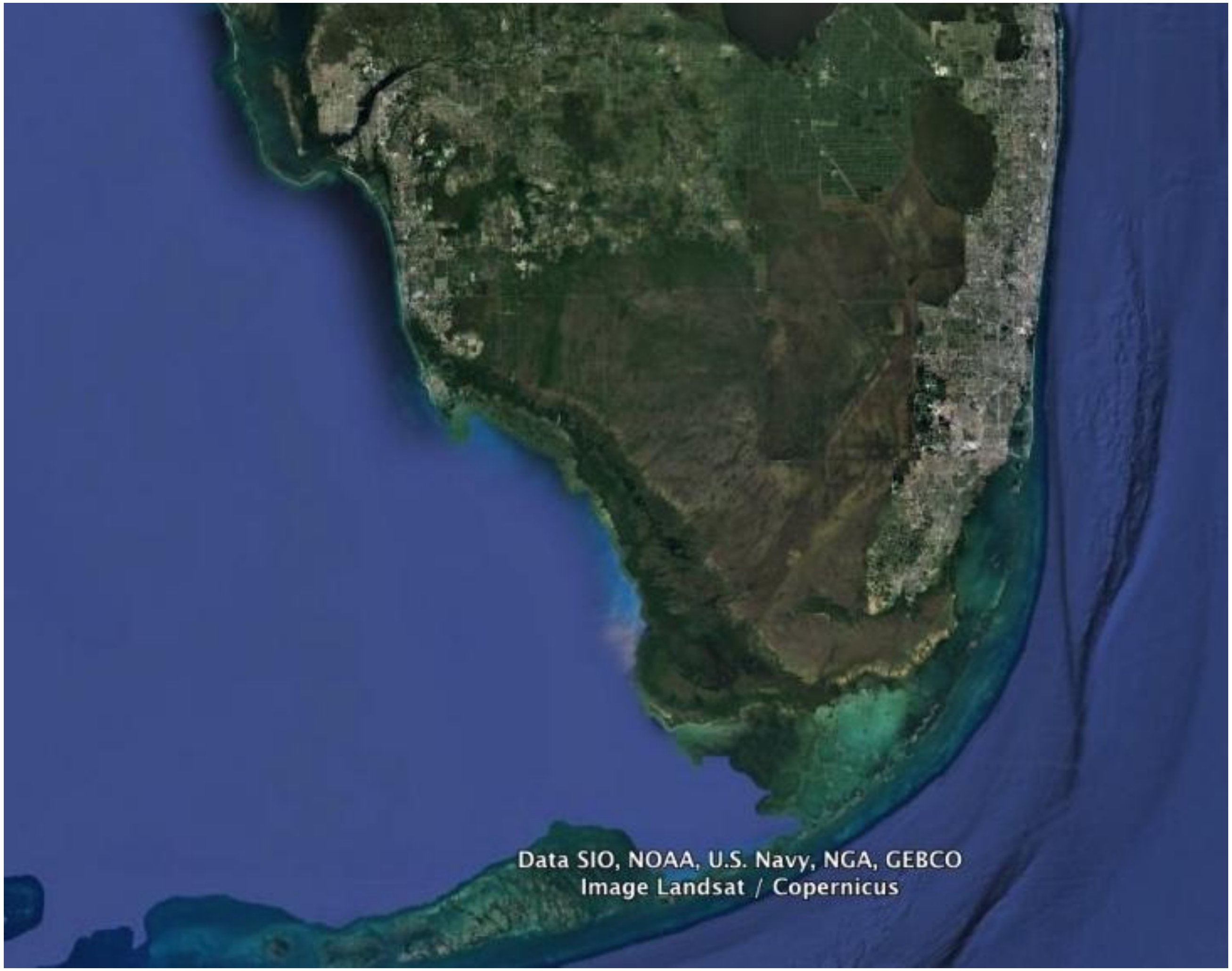
Key Findings and Take-Away Messages

- Exposure of the Pleistocene Miami oolite provides excellent examples of preserved primary sedimentary features of a **“fossilized” ooid sand body**.
- We present a detailed analysis of the **morphologies and dimensions** of the different portions of the Miami oolite by considering outcrops and cores in an airborne LiDAR DTM template.
- The Exumas sand body from GBB consistently comes out as the **best visual and statistical modern analog** to the Miami oolite.
- >100ky of subaerial exposure and meteoric diagenesis including karst has **not significantly altered** the morphology of the Miami oolite
- The Miami oolite serves as a **key reference example** for comparison to Holocene sand units in the Bahamas, and more importantly, subsurface examples in the geologic record.

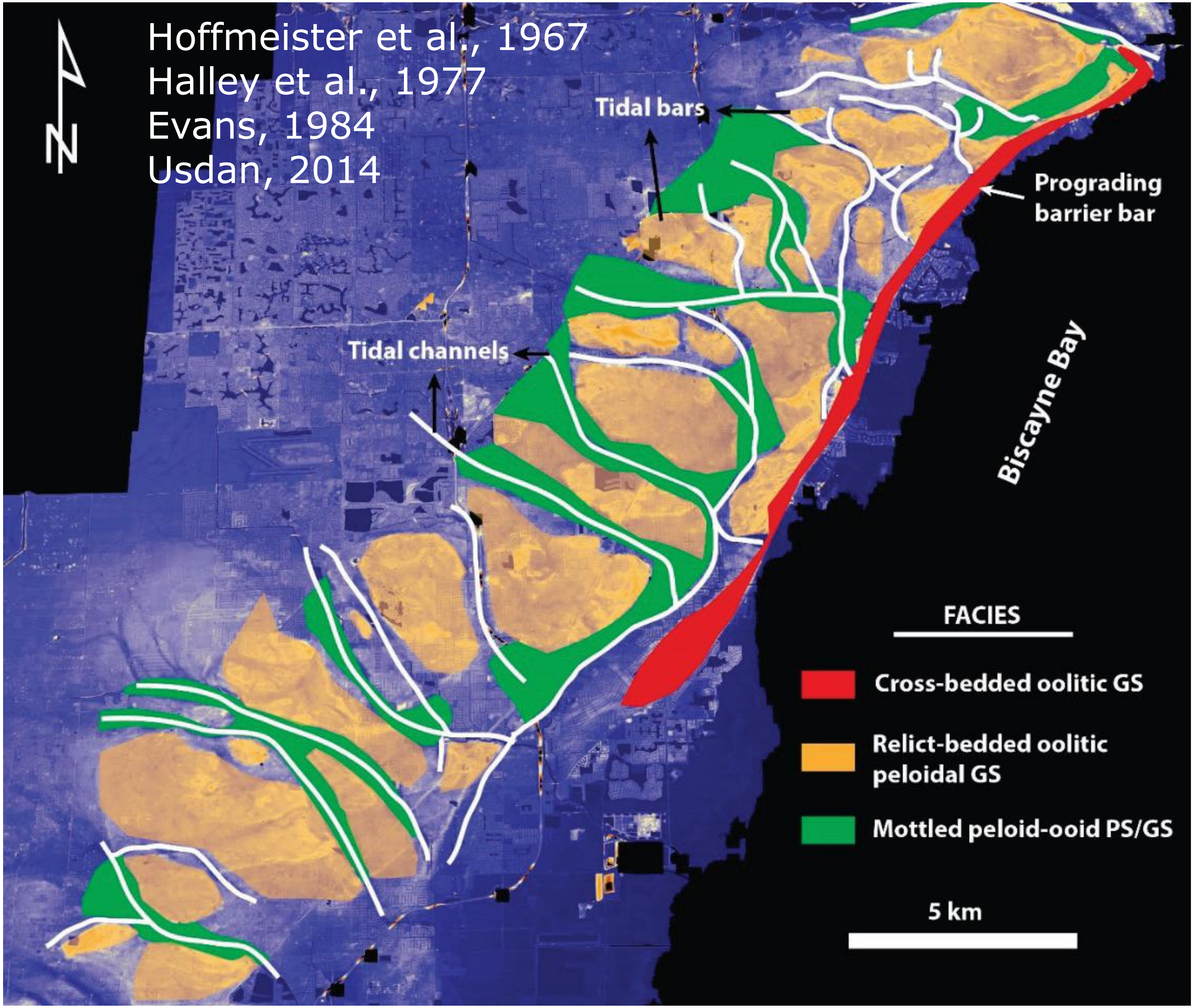

OOID

Location of the Miami Oolite

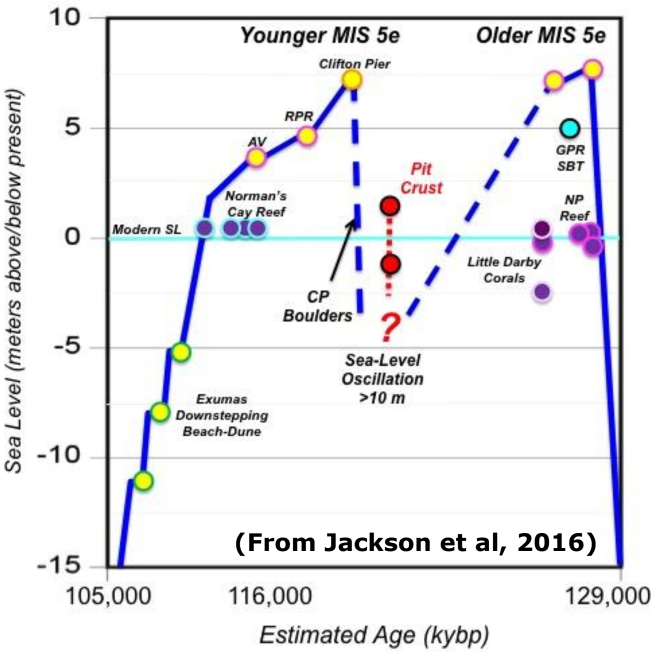


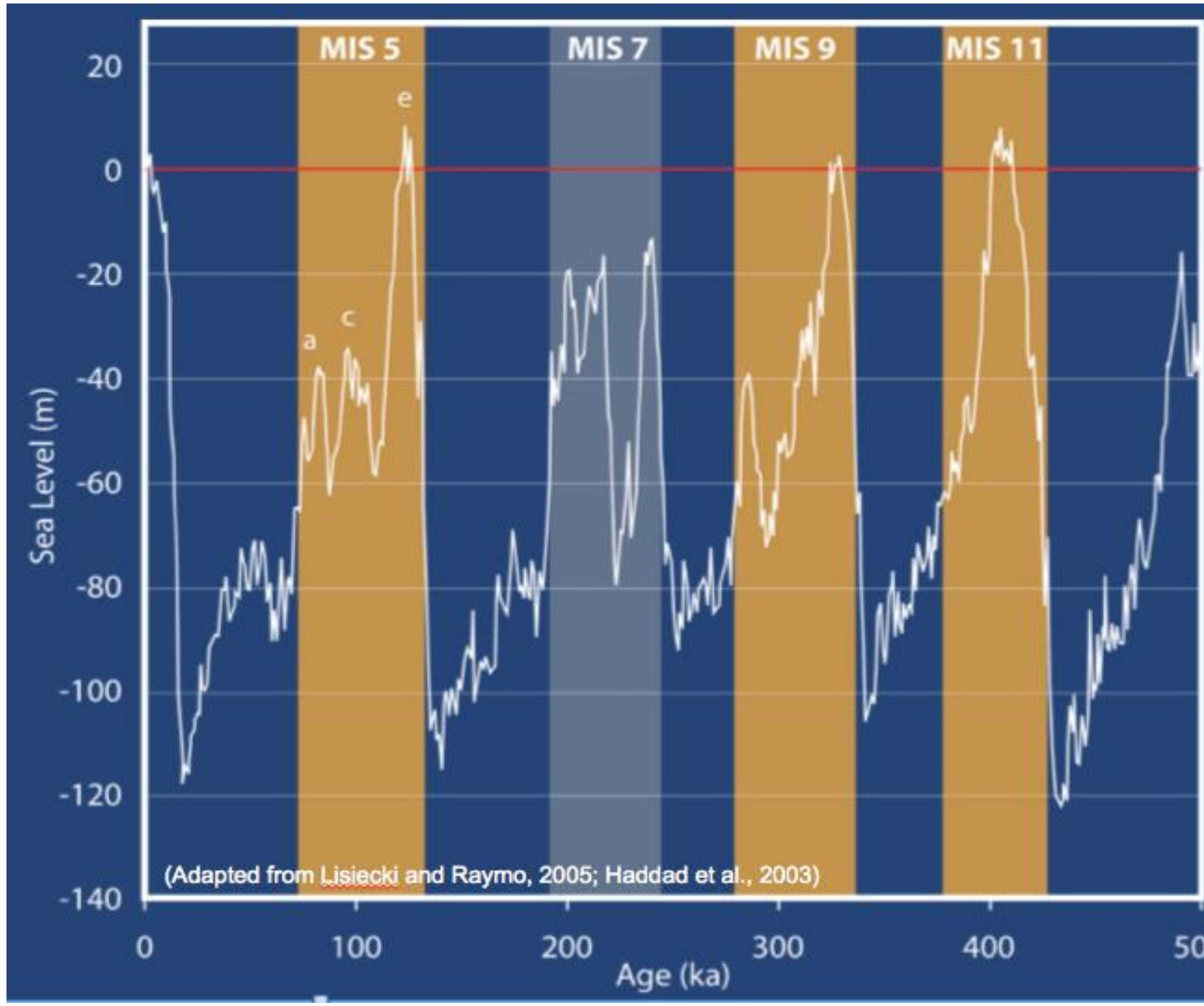


Depositional Setting of the Miami Oolite



Depositional Timing for the Miami Oolite

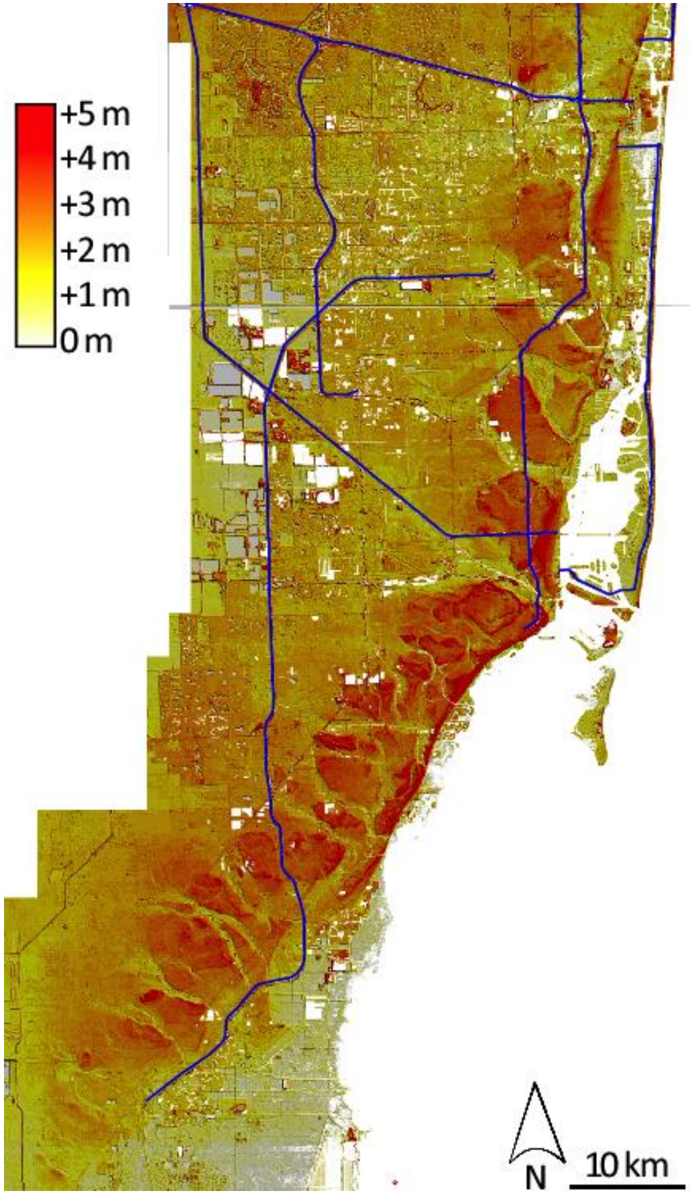




Miami oolite:

- Formed during **MIS 5e at sea-level >6m higher** than today
- Subaerially exposed and **undergoing meteoric diagenesis ever since**

New Perspective of Miami Oolite

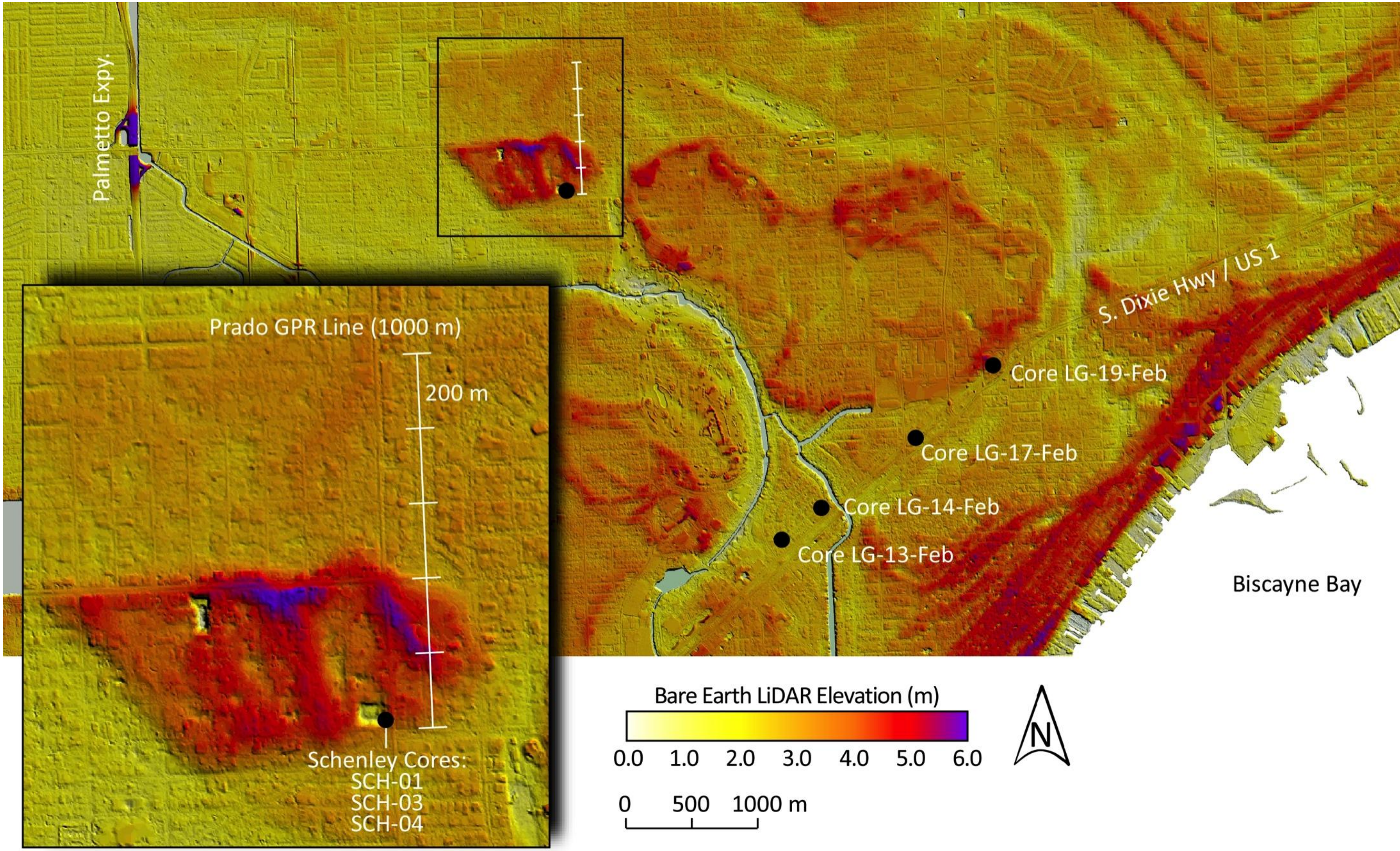


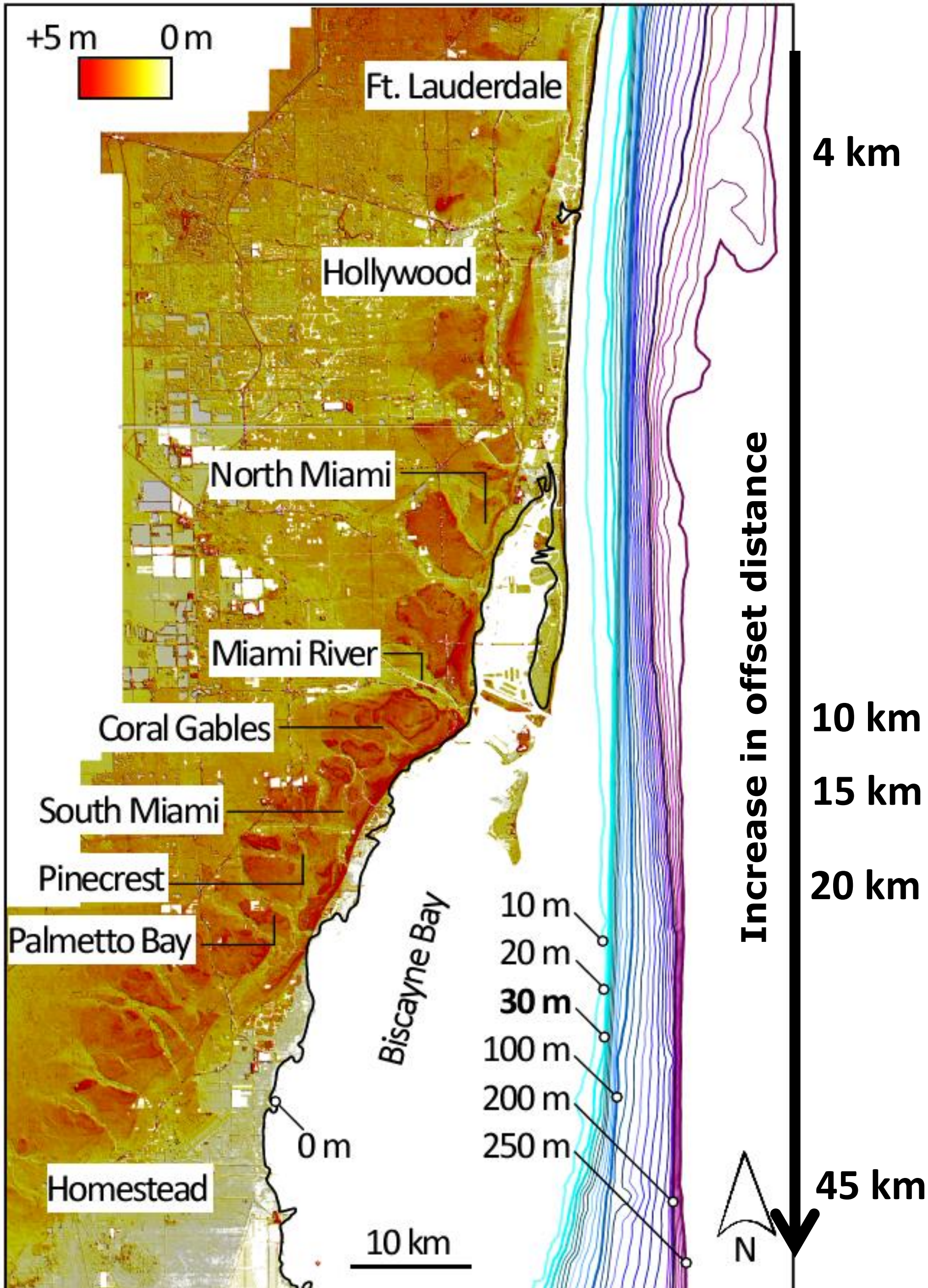
Airborne LiDAR (Light Detection And Ranging) technology was acquired over the breadth of the Miami area (1800 km^2) to create more accurate elevation maps for assessing flooding potential.

The LiDAR-based bare-earth digital terrain model (DTM) was derived from the internet accessible portal of the South Florida Water Management District GIS: http://my.sfwmd.gov/gisapps/sfwmdxwebdc/dataviewasp

The horizontal accuracy of the data is less than 1.1 m while vertical accuracy is less than 0.18 m.

New Perspective of Miami Oolite



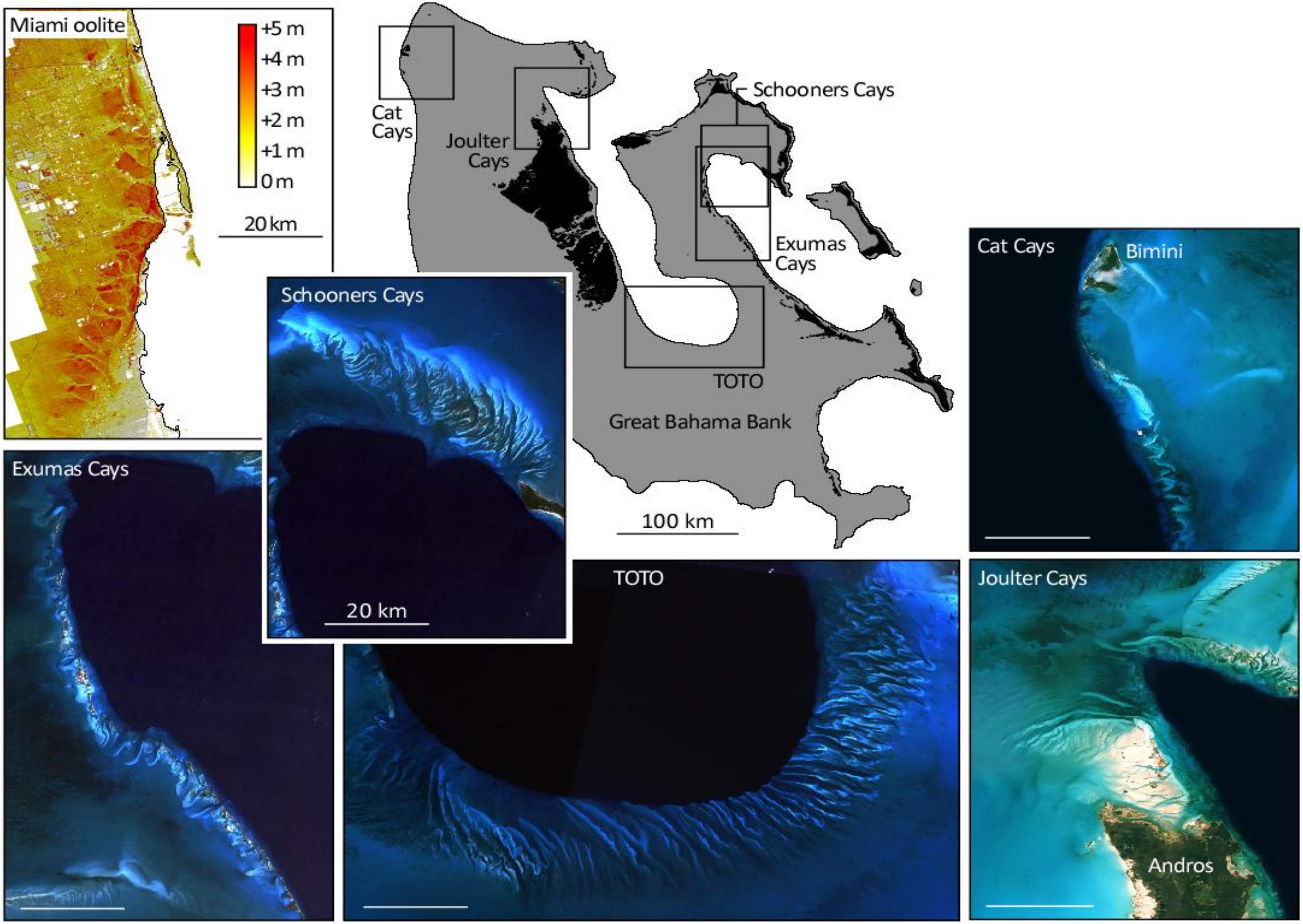


Miami Oolite Sand Body

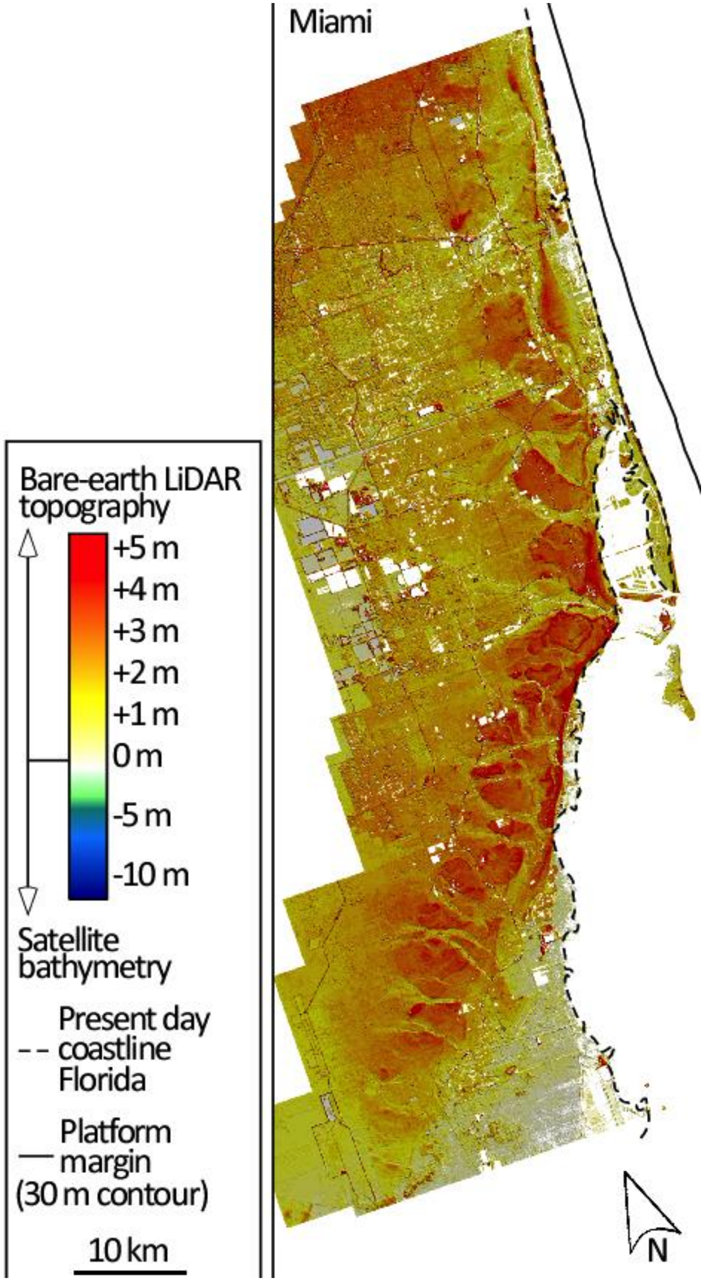
The sand body is:

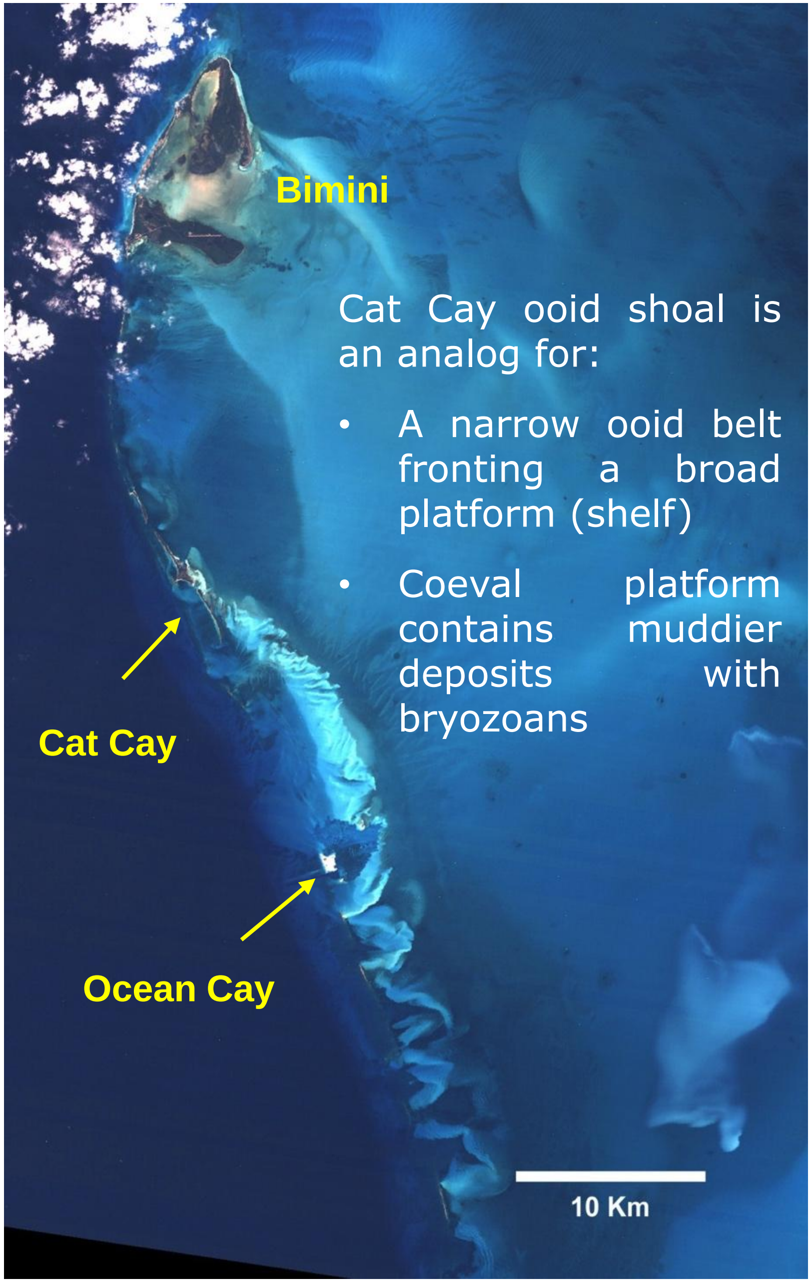
- More than 1000 km^2 in size
- >95 km in length
- 15 km ave dip width
- Clearly made up of highs (shoals or bars, 1-4 km in length and 1-3 km in width) and lows (channels)
- Increasingly offset from the shelf margin to the South

Modern Analogs for Miami Oolite

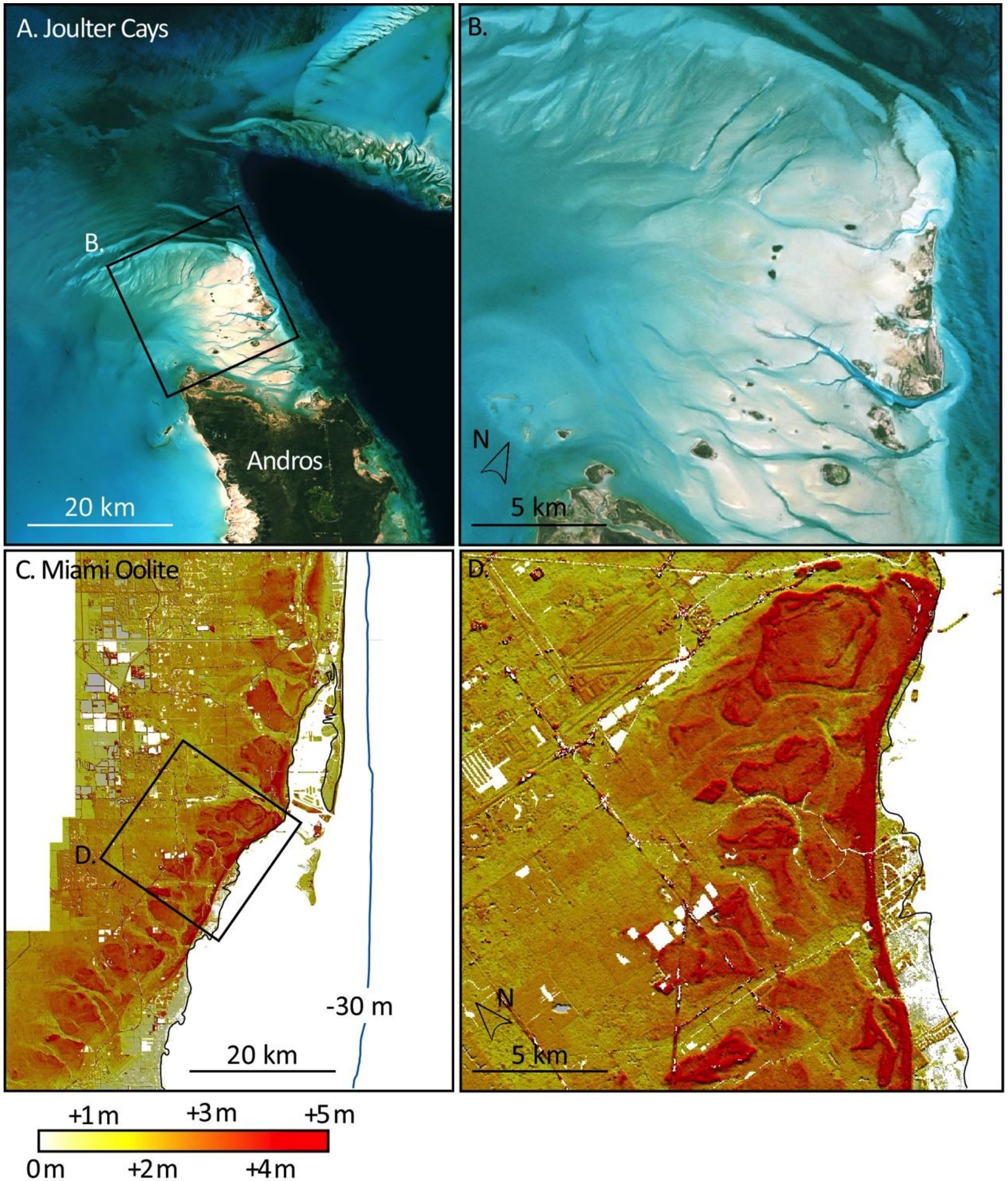


Key Analog for Miami Oolite





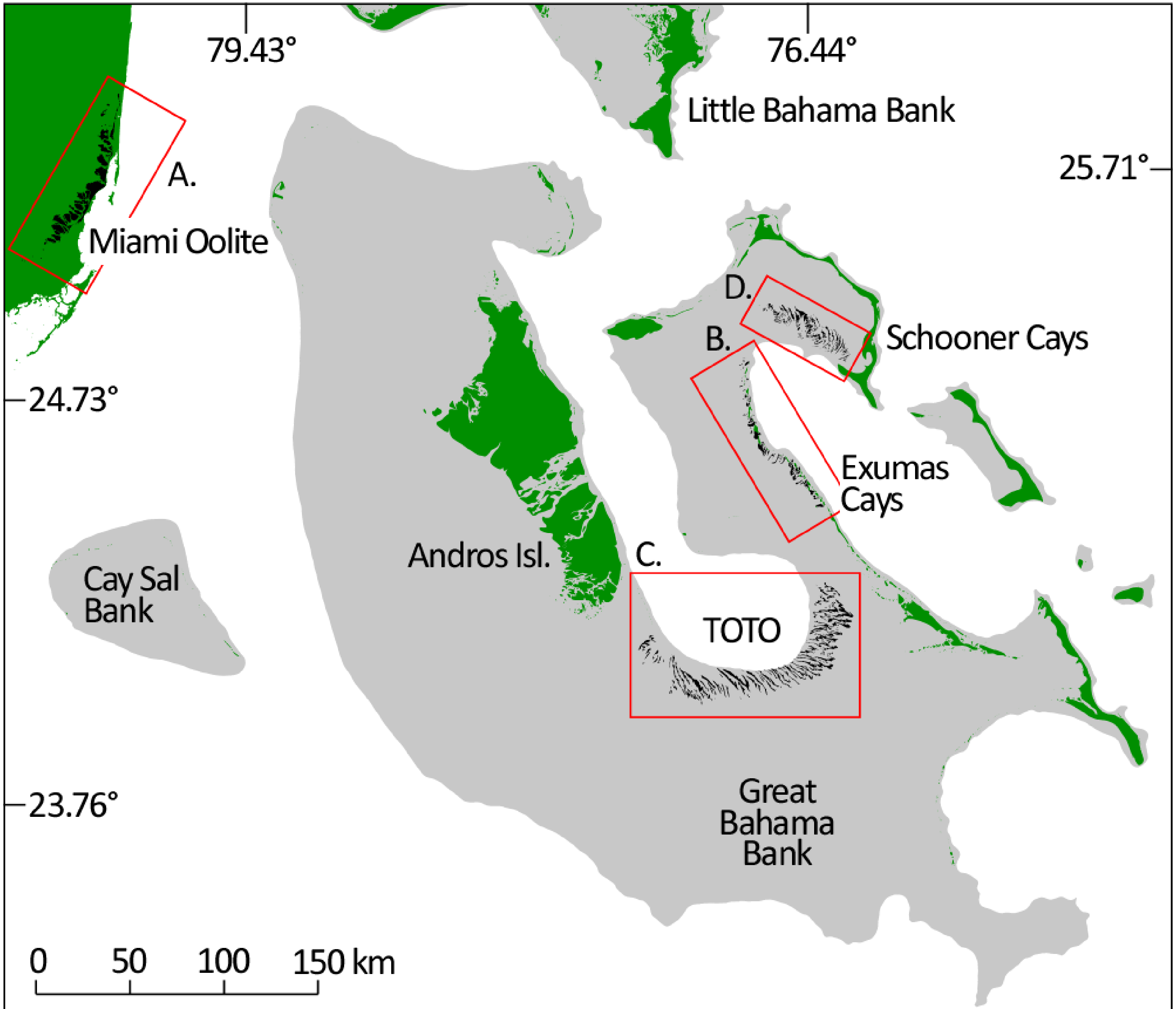
Key Analog for Miami Oolite



Joulters ooid shoal is an analog for:

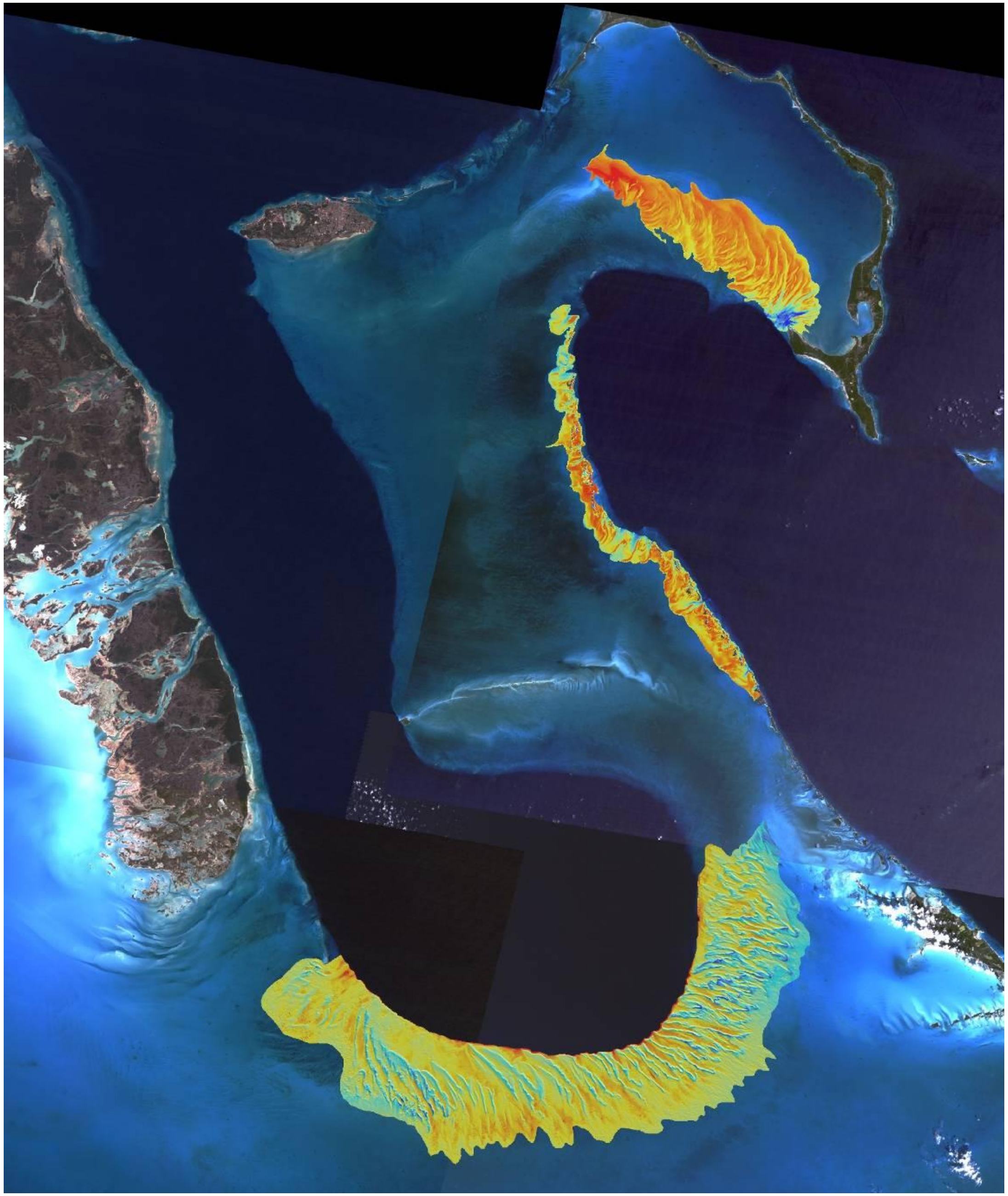
- A broad area of burrowed and reworked shoals (the sand flat)
- A growing seaward barrier bar
- Islands (sand cays) along the barrier bar

Quantitative Comparative Sedimentology



- Strike and dip scale
- Overall morphology
- Aspects of bars and channels
- Margin-parallel highs (islands)

Sandbodies of Great Bahama Bank



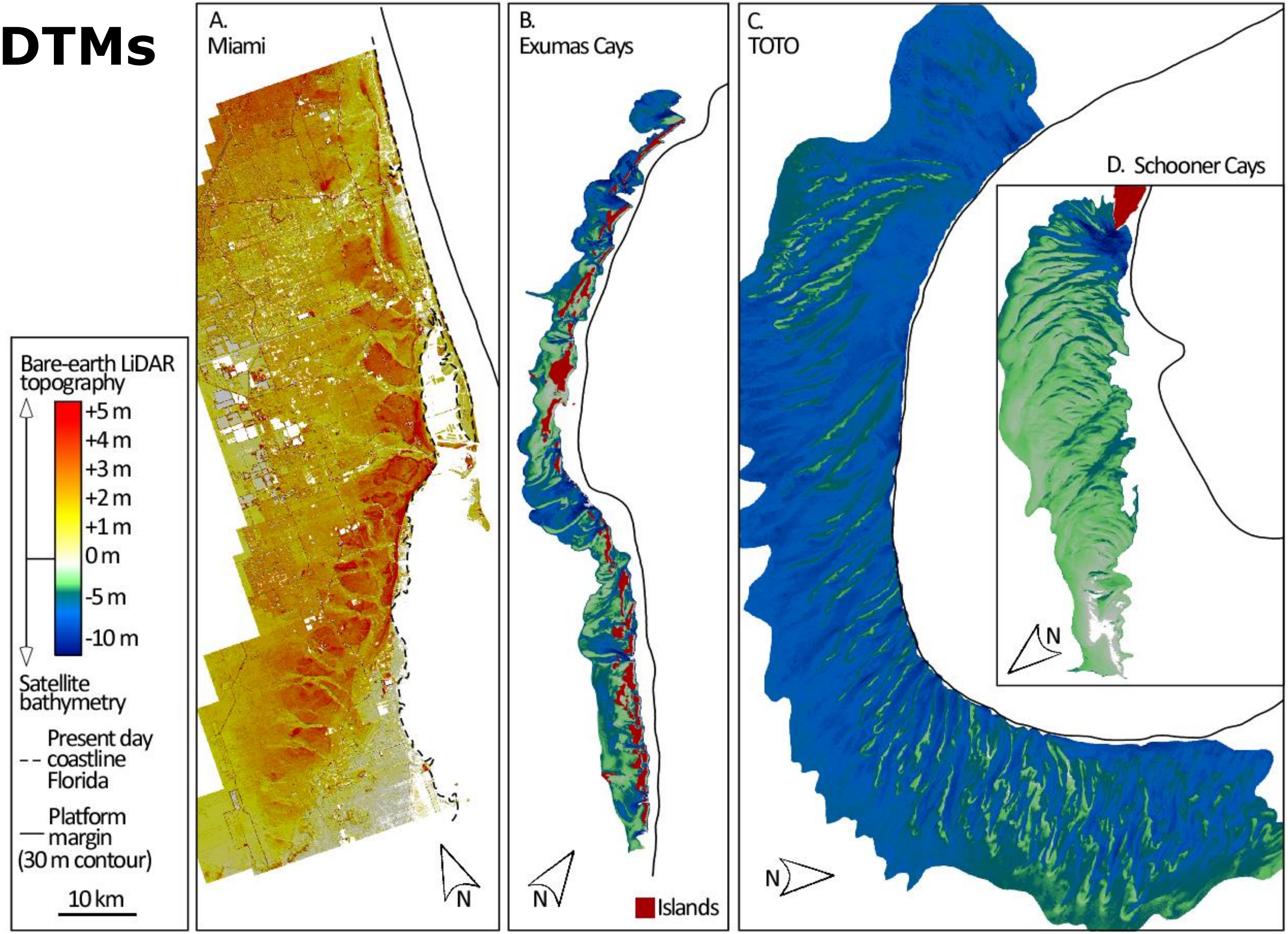
The **Schooners Cays** sand body at the northern end of Exuma Sound contains broad irregular sandbars with relatively narrow channels and few small islands.

Sands associated with tidal channels and islands of the **Exumas** occur primarily as flood tidal deltas.

Rimming the southern end of **TOTO** is the broadest expanse of "high-energy" sands found in the Bahamas, generally characterized by narrow sandbars separated by wide, deep channels and a lack of islands.

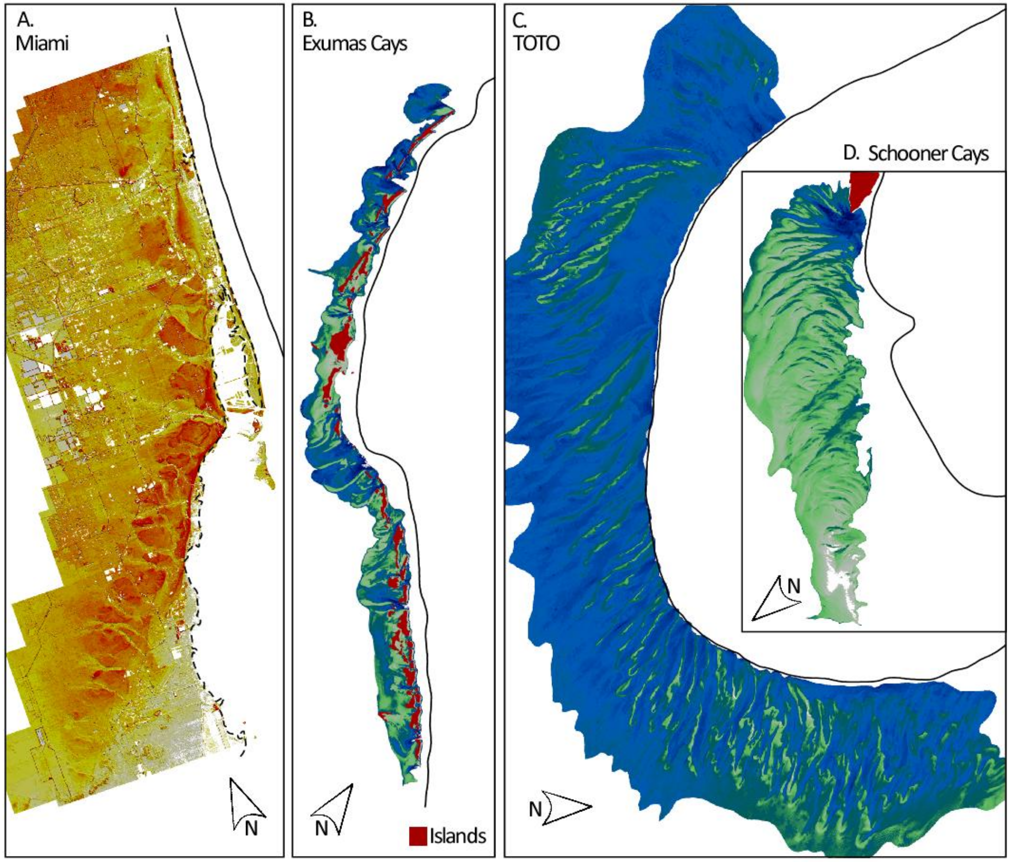
(From Harris et al, 2010 and 2011)

DTMs



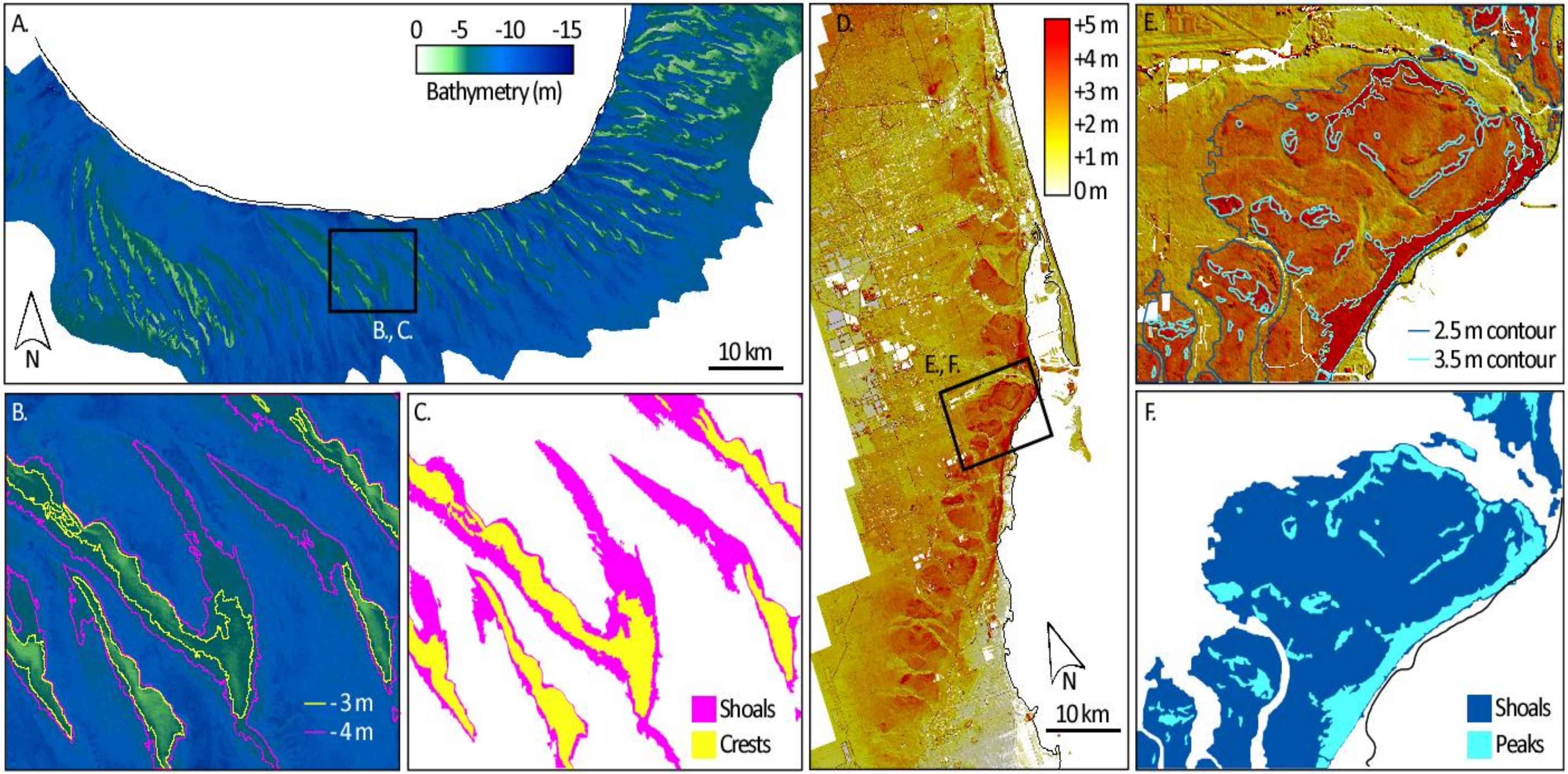
A. Miami
B. Exumas Cays
C. TOTO
D. Schooner Cays
Bare-earth LiDAR topography
+5 m
+4 m
+3 m
+2 m
+1 m
0 m
-5 m
-10 m
Satellite bathymetry
Present day coastline Florida
Platform margin (30 m contour)
10 km
Islands
N
N
N
N

Comparing the Four Sand Bodies

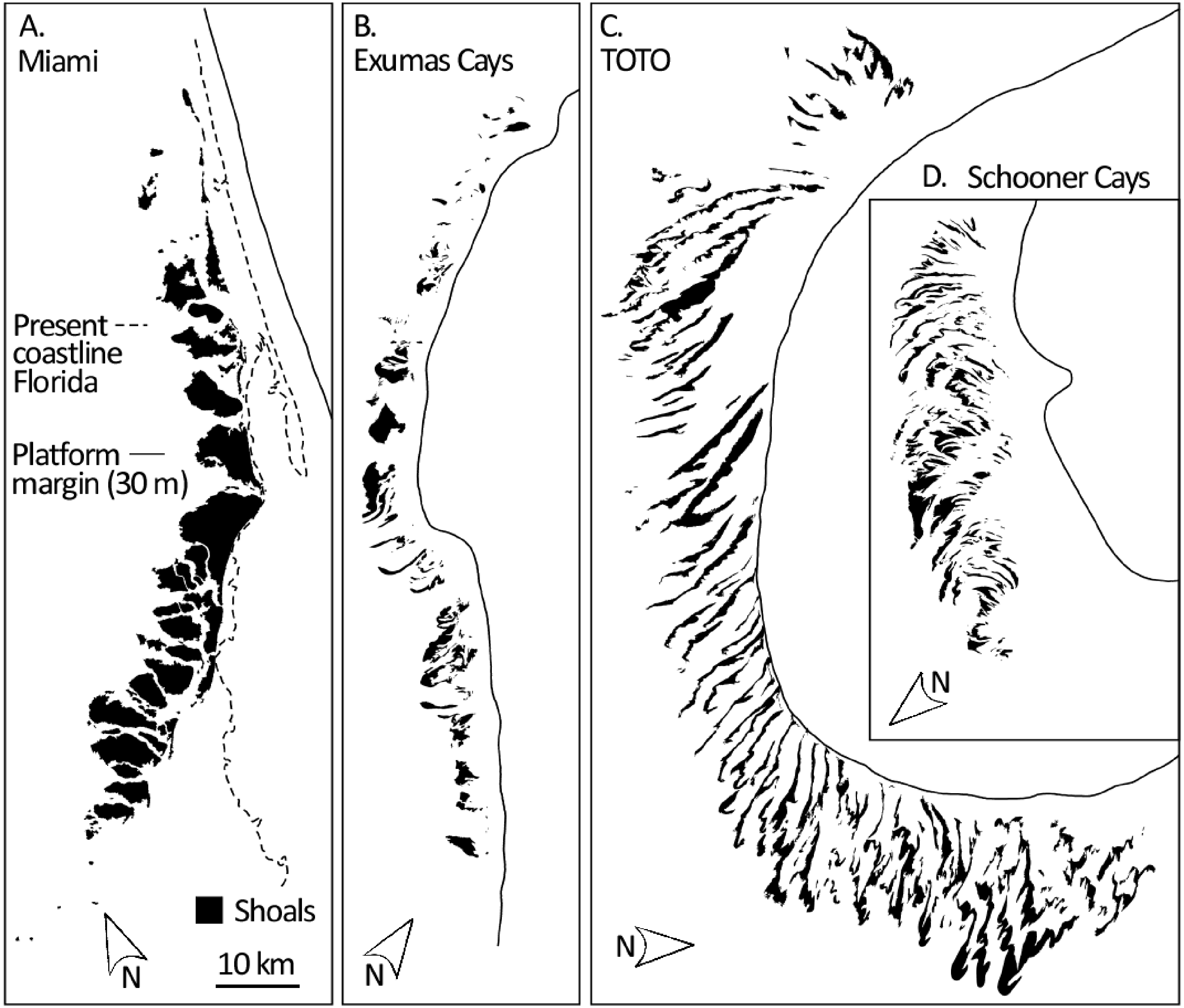


		Shoals		Channels			
Sand Body	**Total area (sq. km)**	**Area (sq. km)**	**Proportion (%)**	**Area (sq. km)**	**Proportion (%)**	**Strike length**	**Dip width**
Miami oolite	1,000	324	32.40%	676	67.60%	95 km	15 km
Exumas Cays	650	90	13.85%	560	86.15%	95 km	5 km
Schooners Cays	610	115	18.85%	495	81.15%	55 km	15 km
TOTO	2,500	430	17.20%	2,070	82.80%	150 km	15 km

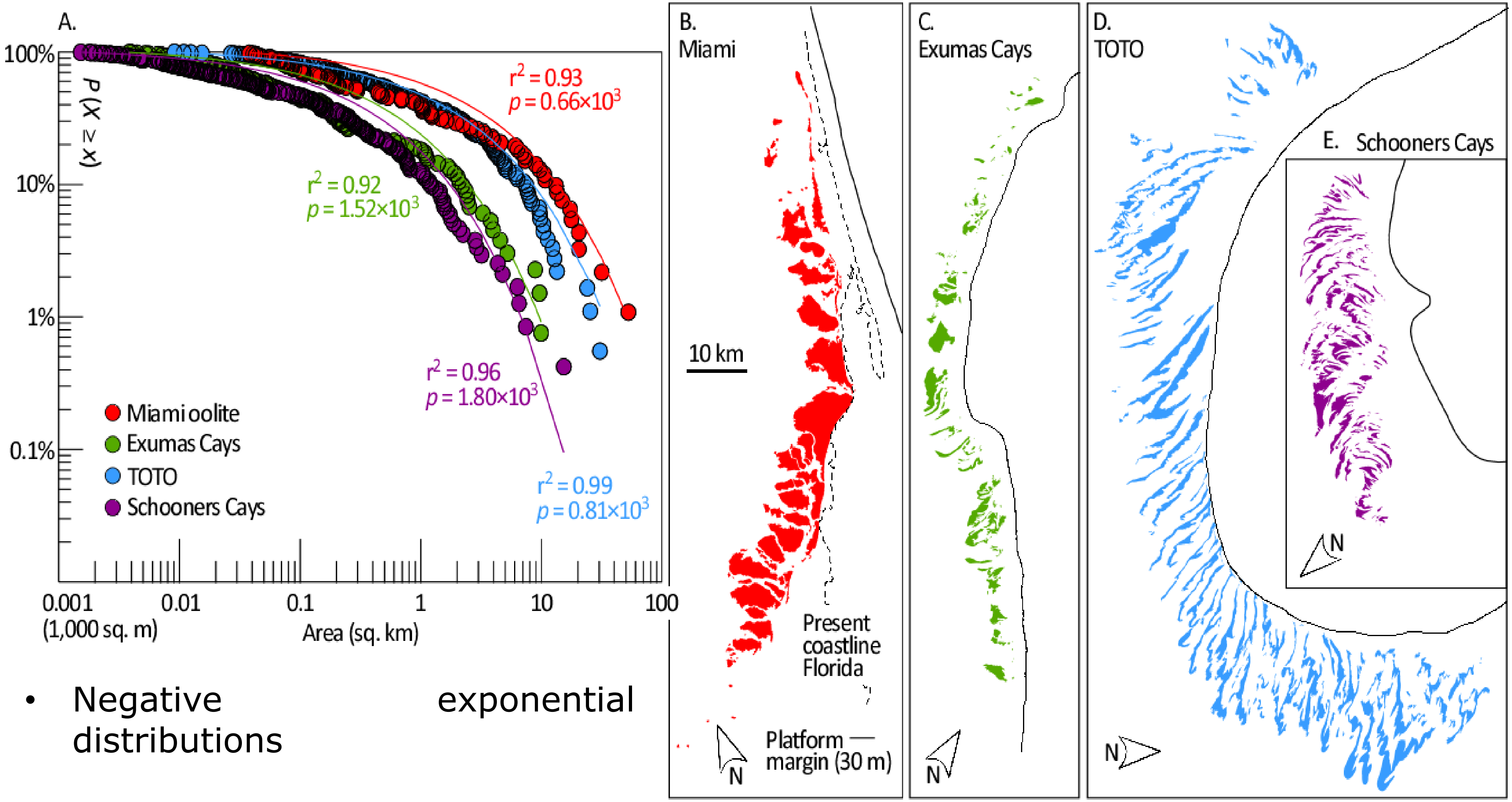
Shoal (Bar) Interpretation



Shoal (Bar) Delineation

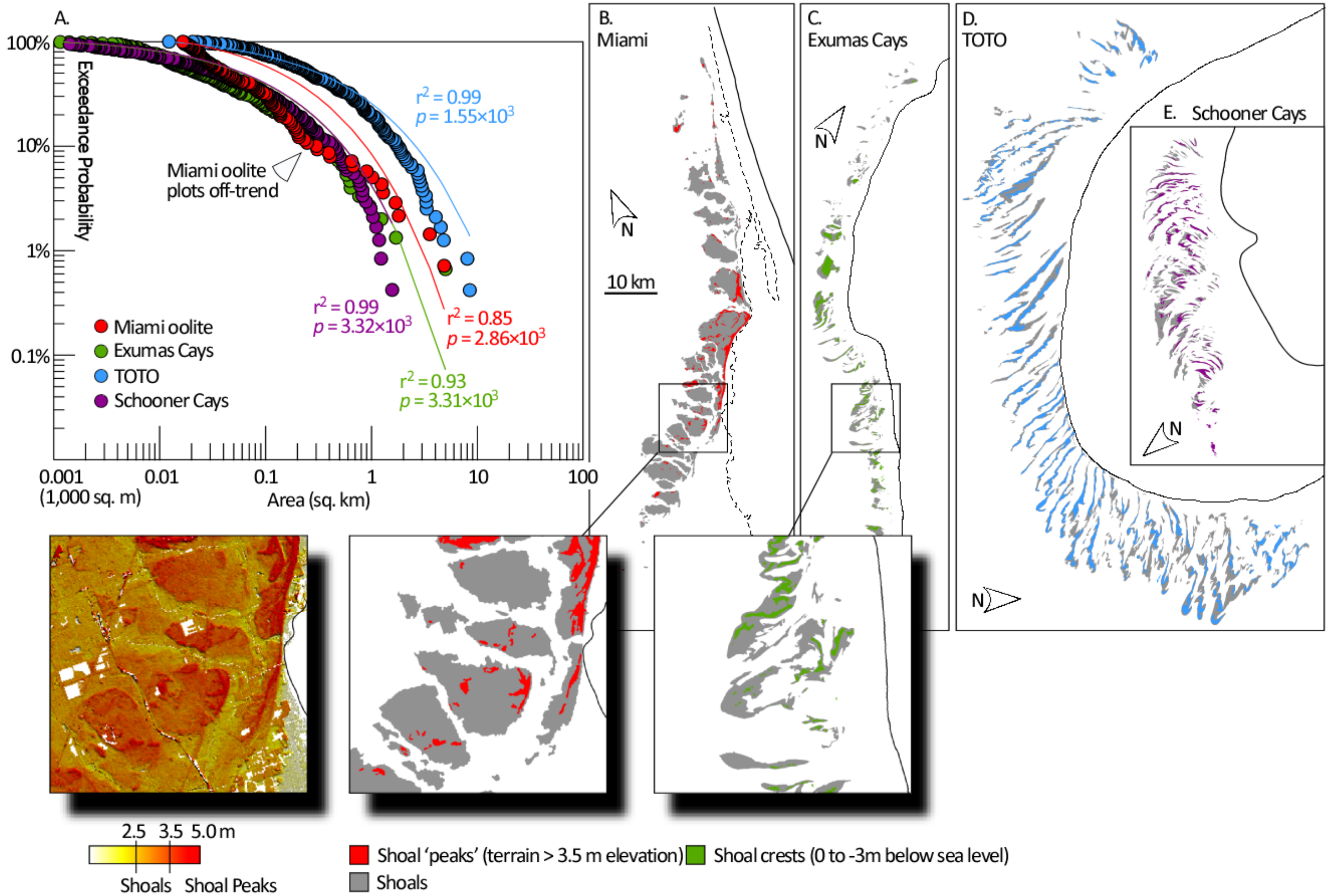


Shoal (Bar) Size Distribution

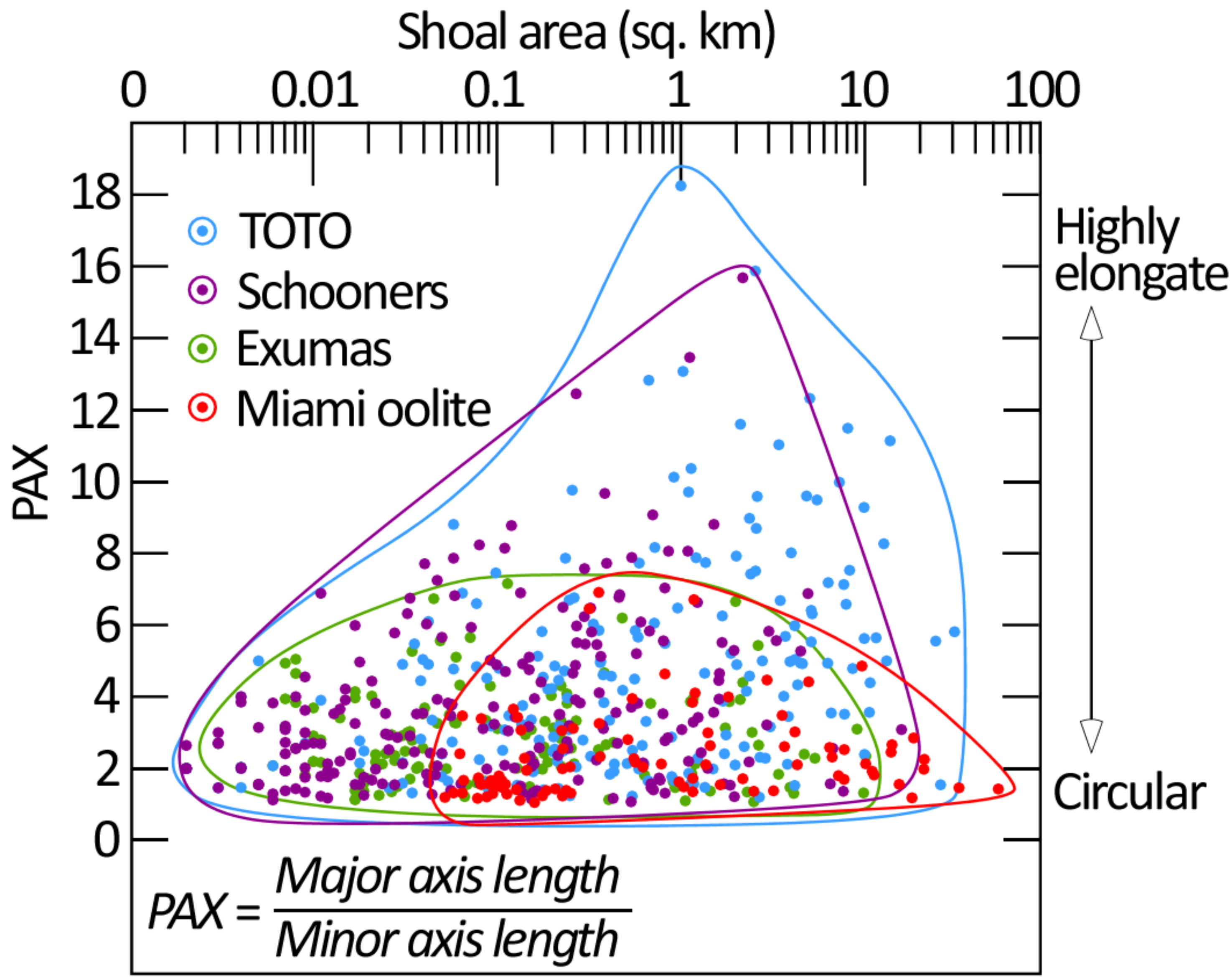


- Negative exponential distributions
- In terms of the size-frequency distribution, the Miami oolite shoals are broadly consistent with the three Holocene analogs

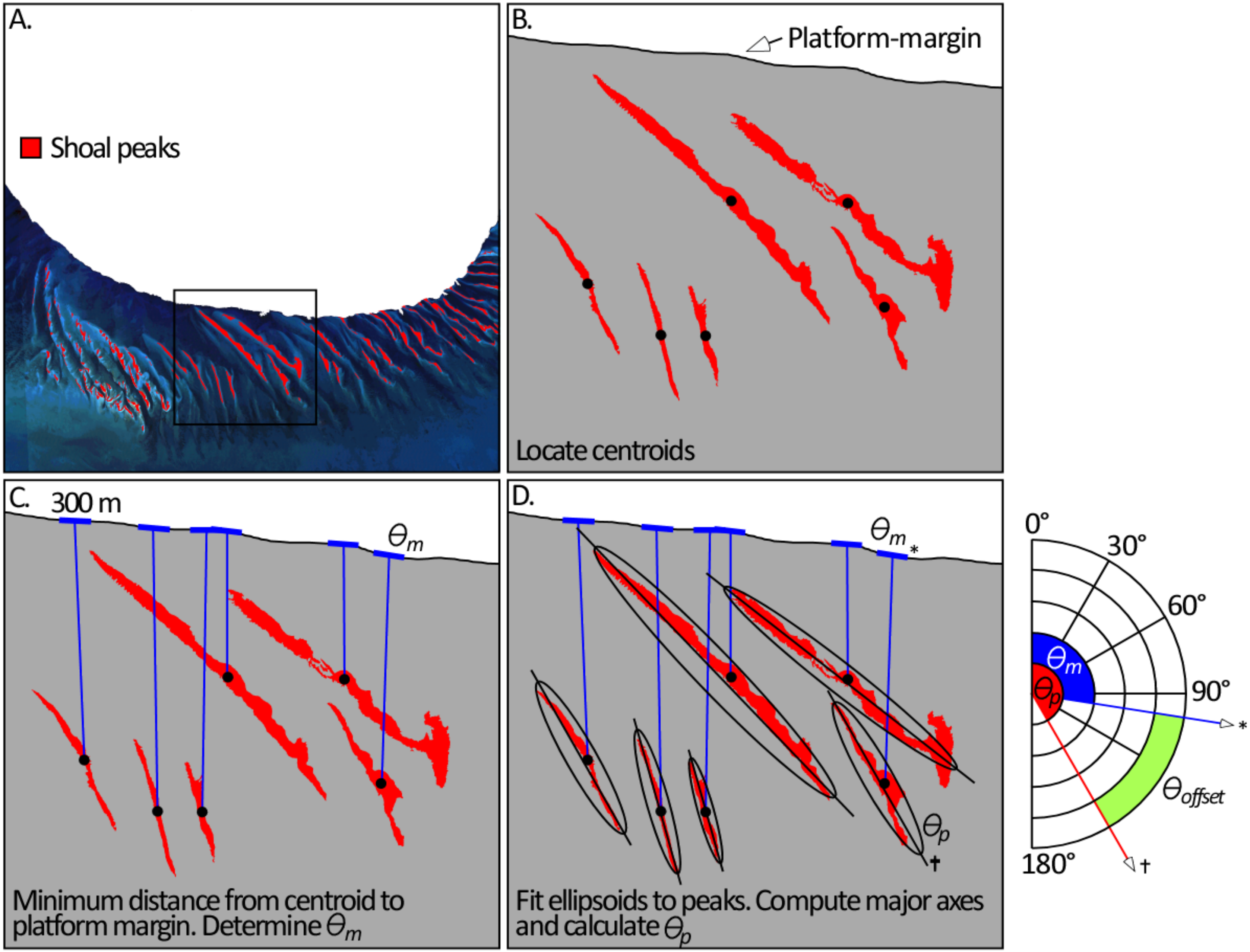
Shoal (Bar) Crest Size Distribution



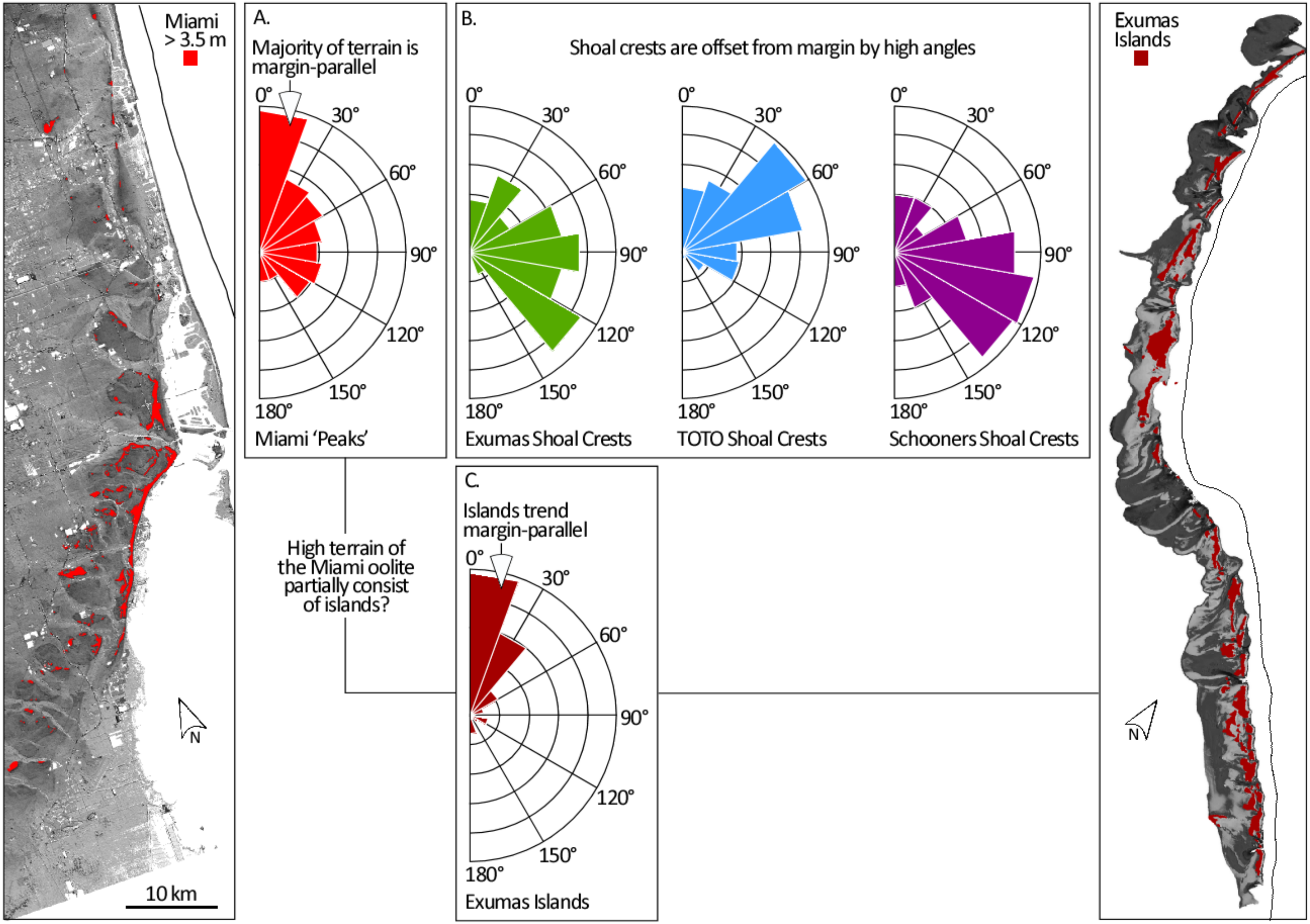
Shoal (Bar) Shapes



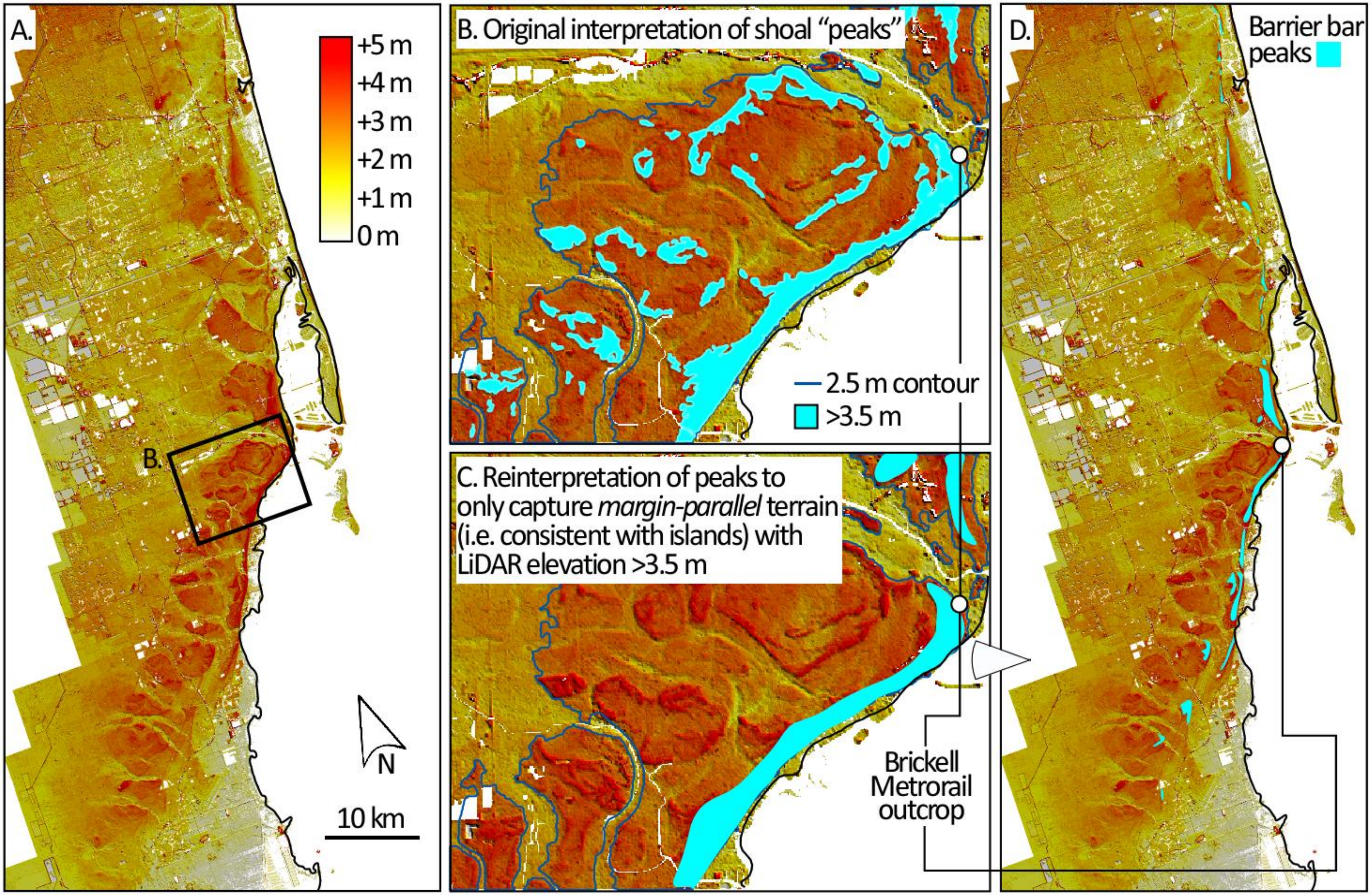
Deriving Shoal (Bar) Orientation



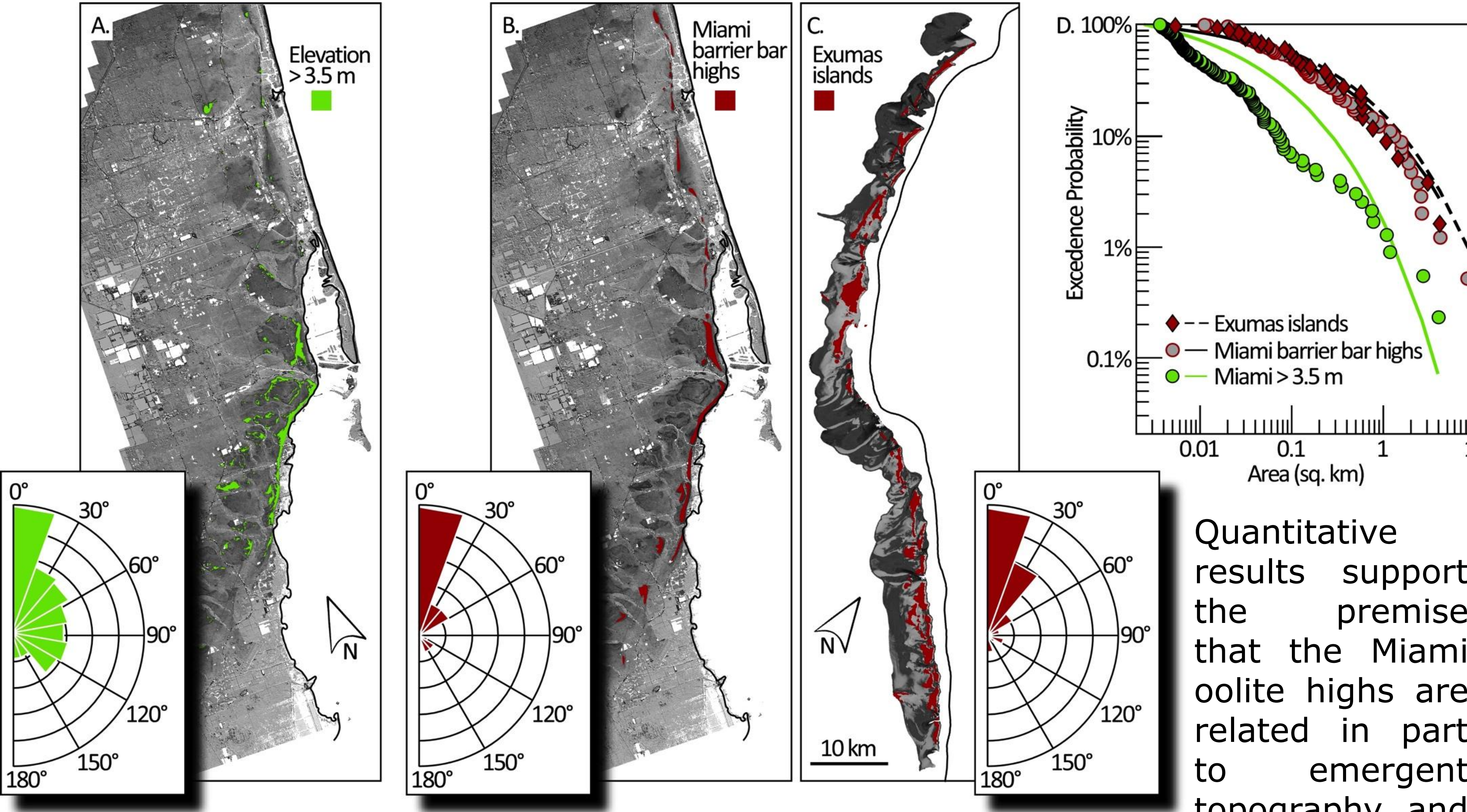
Orientation of Shoal (Bar) Crests



Reinterpretation of Miami Oolite Highs

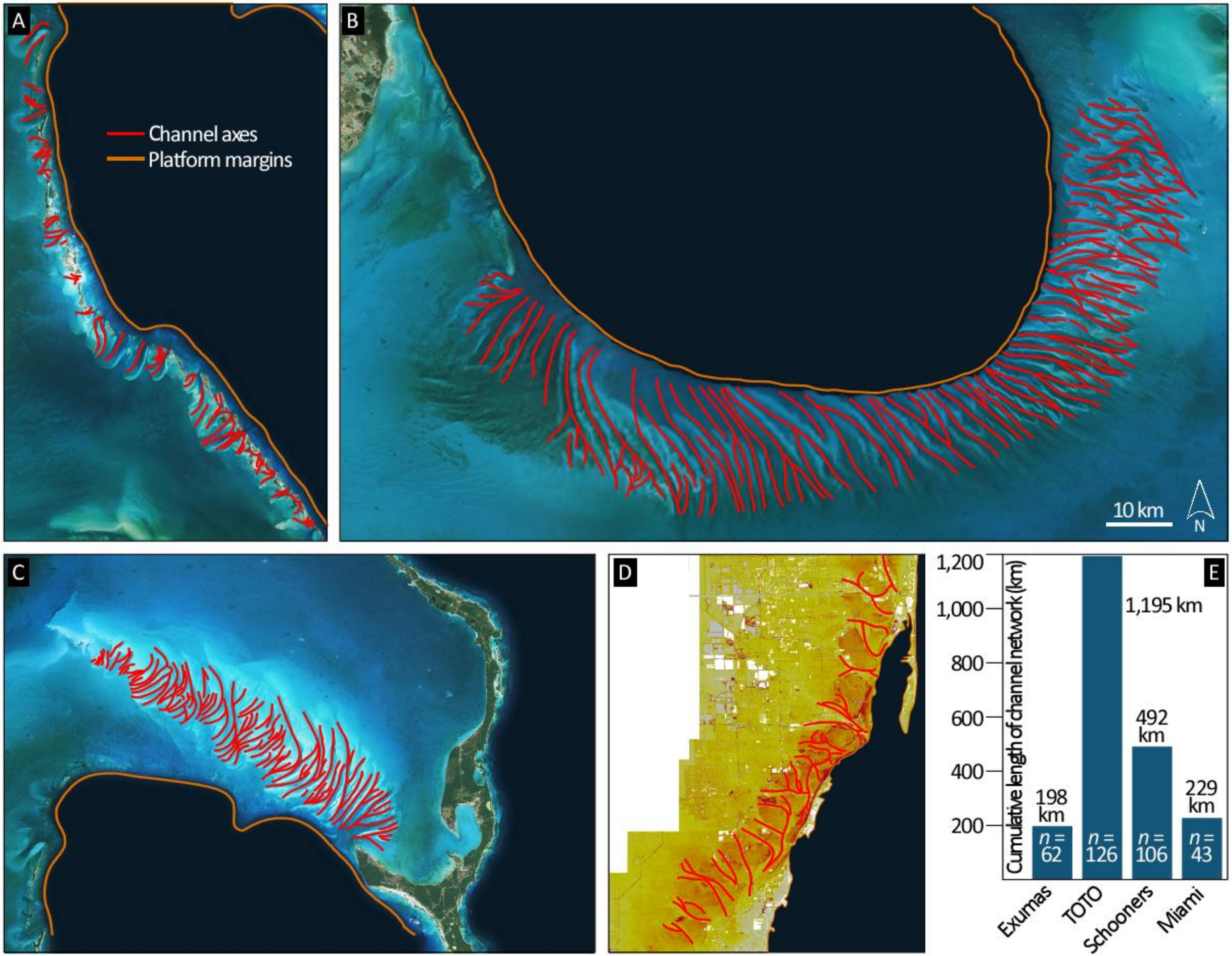


Orientation of Reinterpreted Shoal Crests

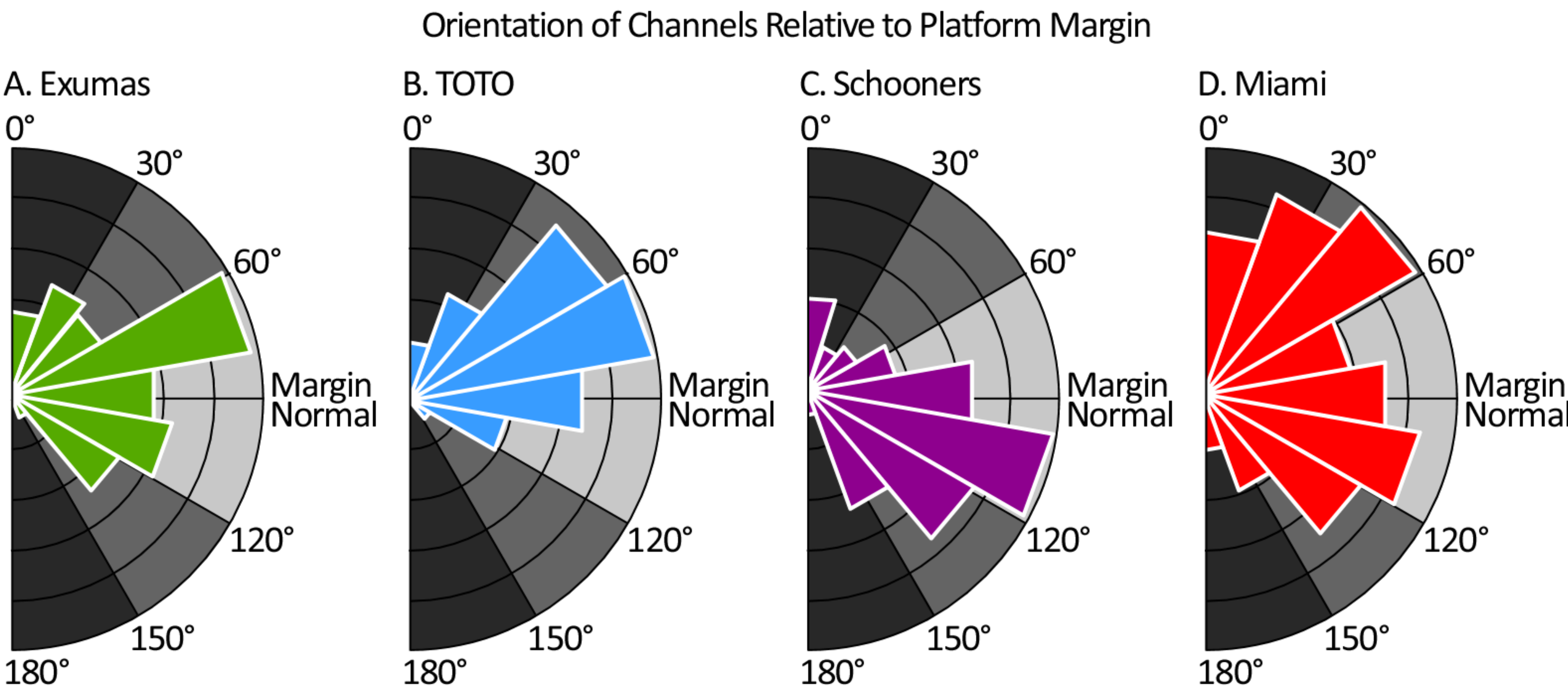


Quantitative results support the premise that the Miami oolite highs are related in part to emergent topography and its remnants.

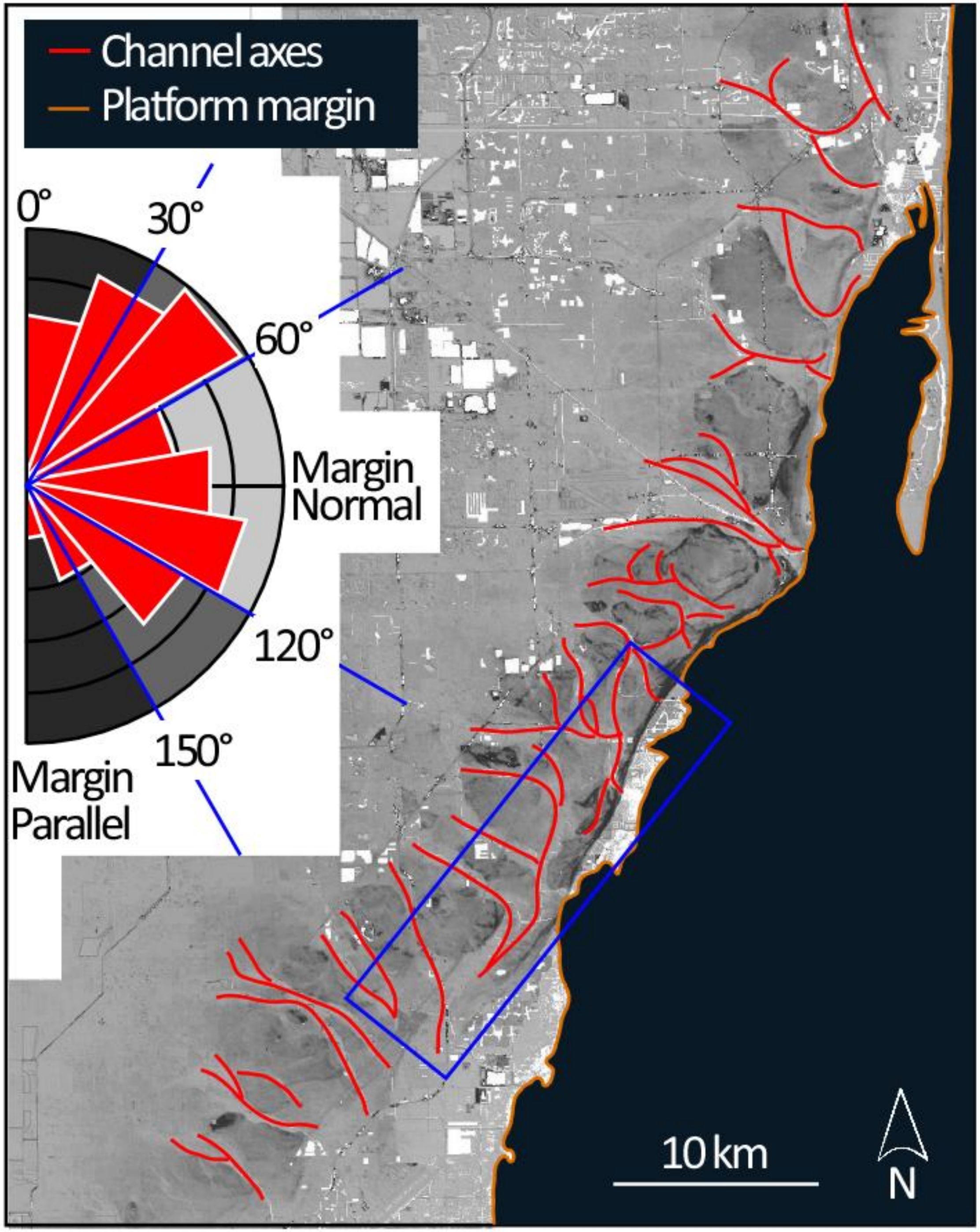
Channel Delineation



Channel Orientations



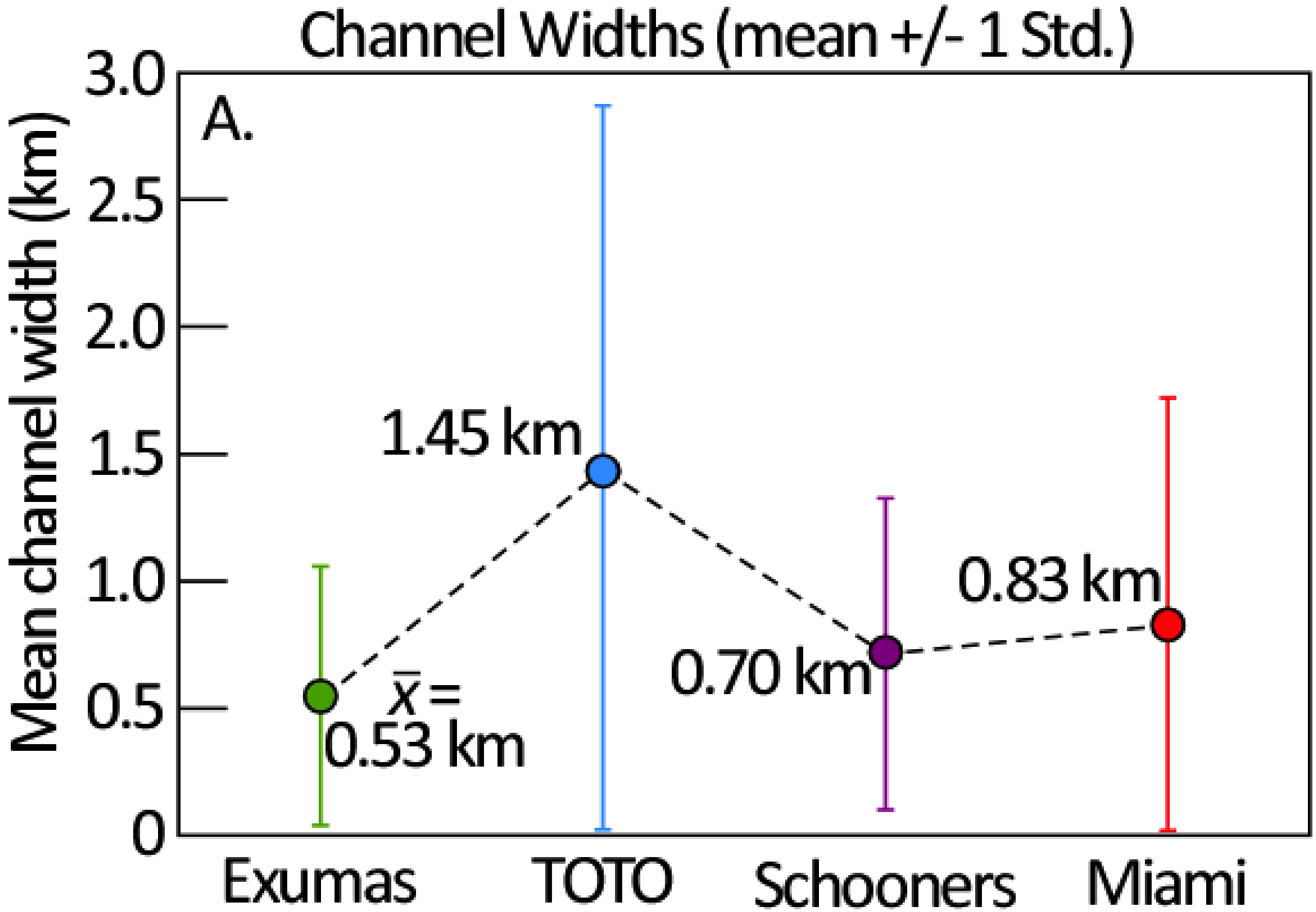
Calculation of channel orientations indicates the channels for the three modern sand bodies are orientated at high angles to the platform margin, whereas those from the Miami oolite are more variably orientated.



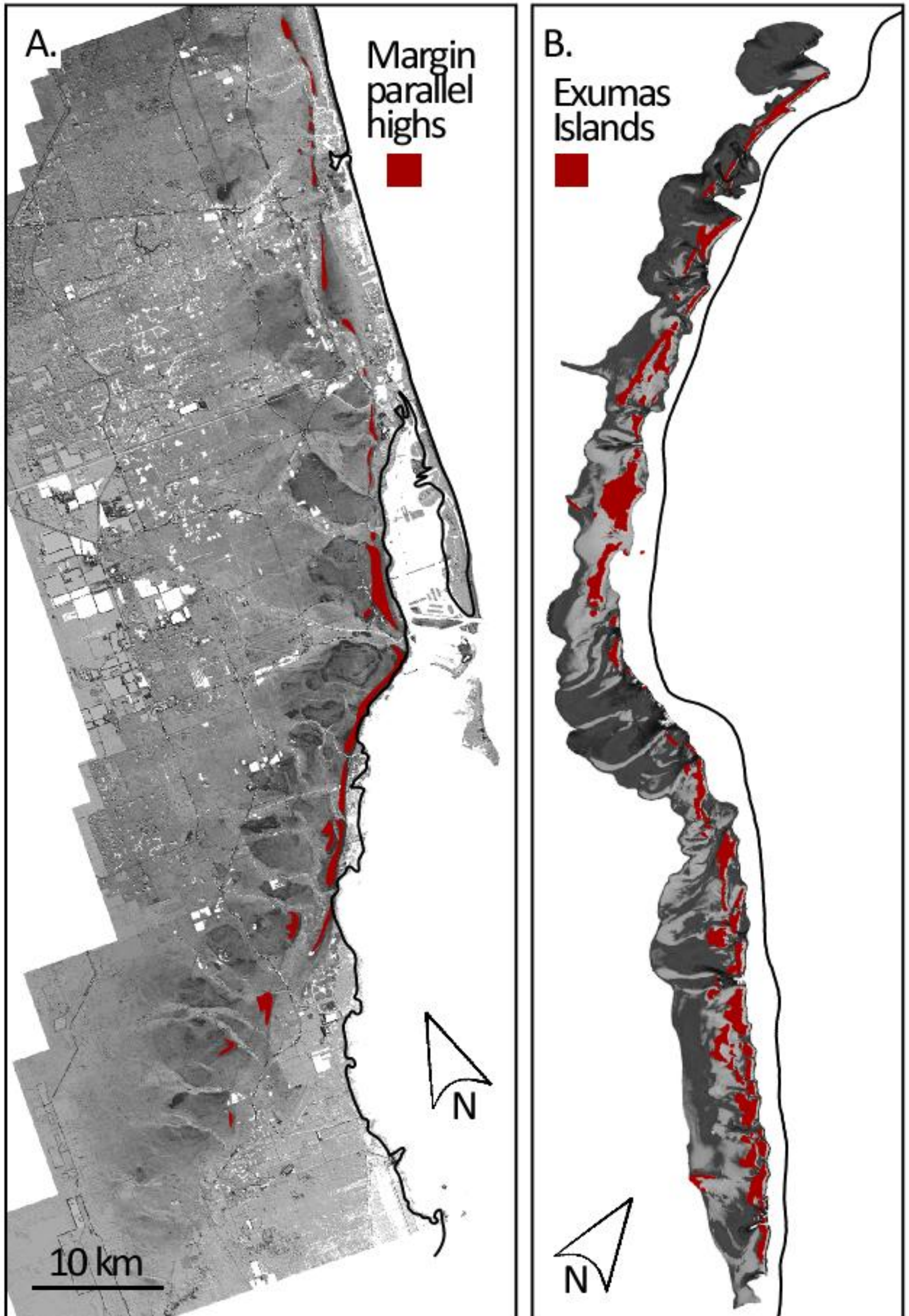
Miami Oolite Channels

- Deviation from margin-normal orientation could be depositional (e.g. Schooners Cays)?
- Or influenced by barrier bar

Channel Widths



- The mean and variance for channels from the Exumas, Schooners and the Miami oolite are comparable.
- This similarity suggests that the Pleistocene channels of the Miami oolite might not have been significantly enlarged and modified by dissolution.



Visual (and Statistical) Similarity between the Miami Oolite and the Exumas

Cat Cay is an analog for a narrow ooid belt fronting a broad platform with muddier deposits and containing bryozoans.

Joulters is an analog for a broad area of burrowed and reworked shoals (the sand flat) and a growing seaward barrier bar including sand cays.

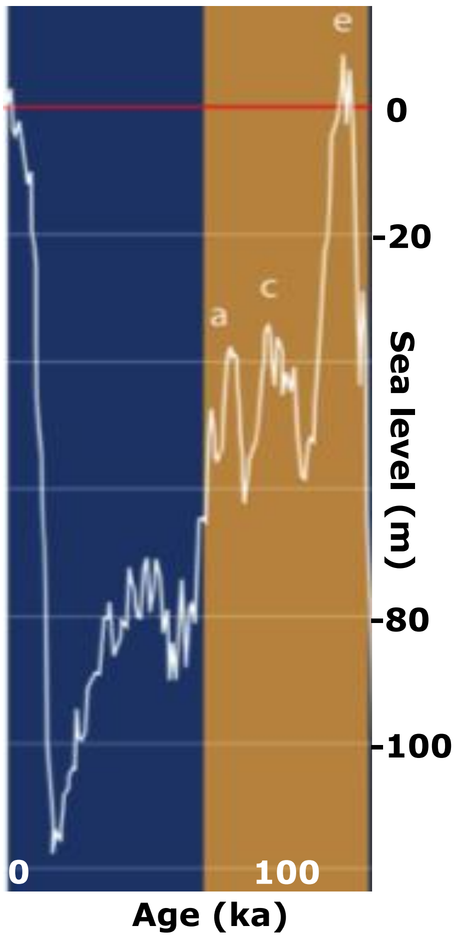
However, the Exumas is the most suitable analog in terms of:

- Strike and dip scale
- Overall morphology
- Several aspects of bars and channels
- Possibly the margin-parallel highs (islands)

Diagenetic Modification

Miami oolite:

- Deposited during MIS 5e at sea-level >6m higher than today
- Subaerially exposed and undergoing meteoric diagenesis for ~115 ka in a tropical climate
- Overprint of surface karst and shallow subsurface caves
- Some degree of surface modification and general lowering (estimated to be ~1.3 m by Halley and Evans, 1983)
- **But depositional morphology of bars and channels amazingly well preserved**



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