# [PS]Satellite Imagery and Geological Interpretation of the Exumas, Great Bahama Bank - An Analog for Carbonate Sand Reservoirs*

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Search and Discovery Article #50200 (2009)
Posted September 7, 2009

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## Abstract

We use a set of processed satellite images, offshore/onshore (DEM), and interpretation maps organized into a GIS for geological interpretation of the Exuma Islands and surrounding carbonate sand bodies of Great Bahama Bank. The overall distribution of carbonate sands; i.e., total sand body, was interpreted by selecting different water depth intervals, and different portions were highlighted for visual analysis and morphometric measurements. We think such results add value to the characterization and modeling of carbonate reservoirs.

The shallowest sands (0 - 1.8 m water depth and likely producing the best reservoir) revealed geologically reasonable patterns of deposition and accounted for 37% of the total sand body. 48 out of the 617 shallowest sand bodies have areas larger than 100,000 $m^2$. Their shape was evaluated using the form-factor shape of Russ (1999) wherein values approaching 1 are more circular and 0 are more irregular. The smallest, shallowest sand bodies have form factors from 0.15 to 0.6, whereas only 6 sand bodies larger than 100,000 $m^2$ have form factors greater than 0.14, indicating larger sand bodies are relatively more irregular compared with smaller sand bodies. The largest, shallowest sand body (16 $km^2$) is highly sinuous and has the lowest form factor of 0.0097.

The total sand body was also divided into flood tidal delta lobes, ebb tidal delta lobes, and sand flats/island-attached sands. Flood tidal delta lobes comprise 85% of the total sand body. The average distance was 2.7 km +/- 1.5 km (with a range from 0 to 7.3 km) from any portion of the flood tidal delta to an ebb-flood dividing line. Fifty-two active tidal channels average 2.9 km and range between ~0.5 and 8.2 km in length. Flood tidal delta lobes average 900 m +/- 650 m from the tidal channels with sediment deposited in the lobes ranging in distance from the tidal channels between 0 to ~4400 m.

Interpreting Pleistocene and Holocene ridges from enhanced satellite imagery of a key island indicates 38% of the island is Pleistocene at the surface, and the Holocene ridges were deposited around the Pleistocene topography in a complex fashion. Integrating elevations with the interpretation map shows Holocene ridges have elevations from near sea level to 12 m (mean elevation of 7.7 +/- 2.5 m ) and Pleistocene landforms have elevations from near sea level to 19 m (mean elevation of 9.3 +/- 3 m).

# Satellite Imagery and Geological Interpretation of the Exumas, Great Bahama Bank - An Analog for Carbonate Sand Reservoirs

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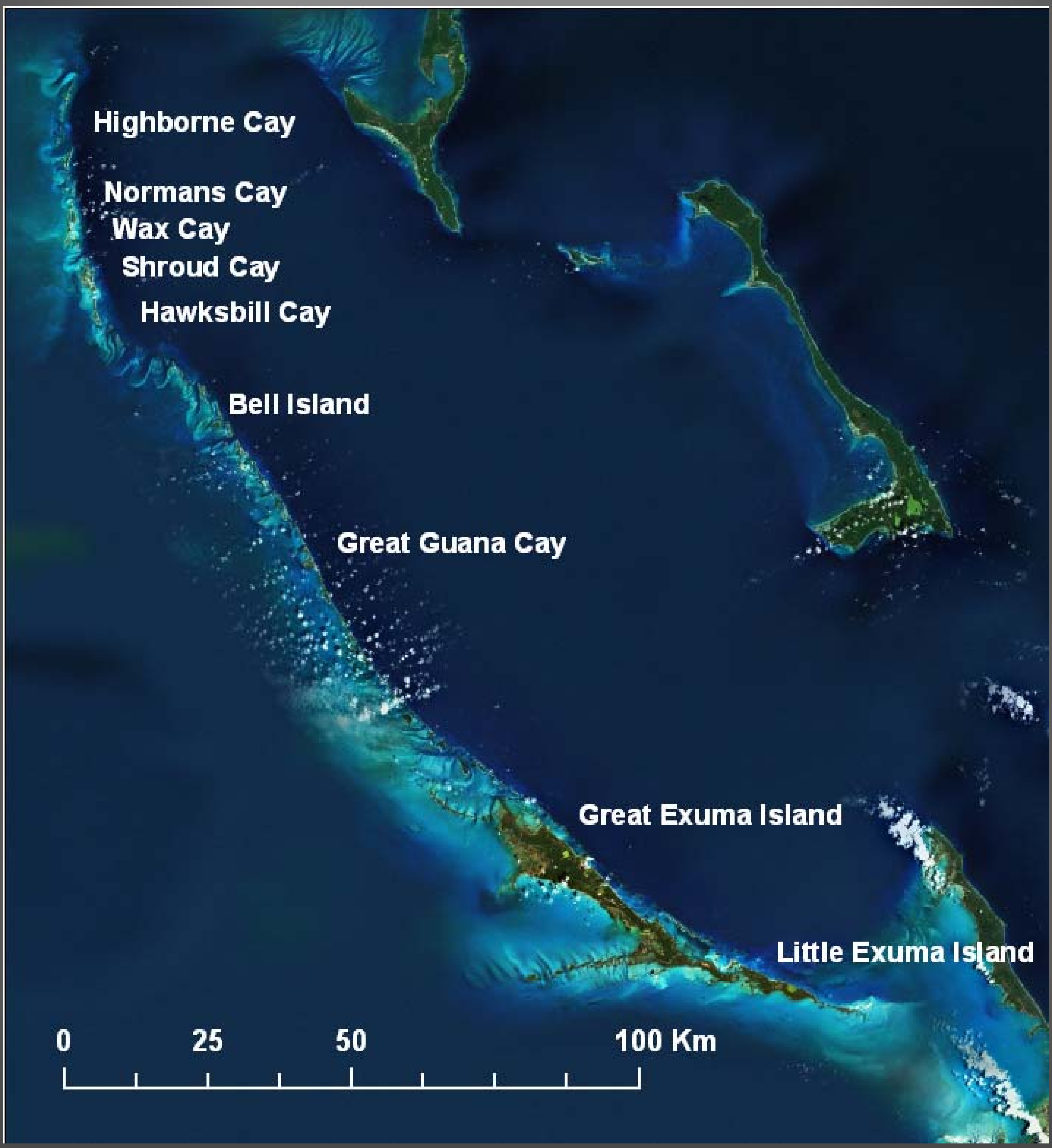
James Ellis, *Ellis GeoSpatial, Walnut Creek, CA*

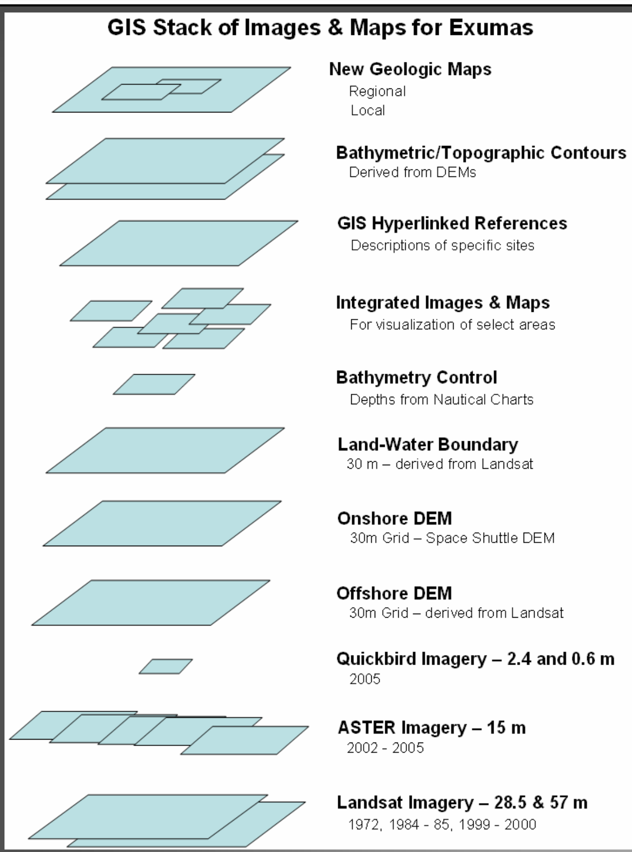
## Rationale for Study

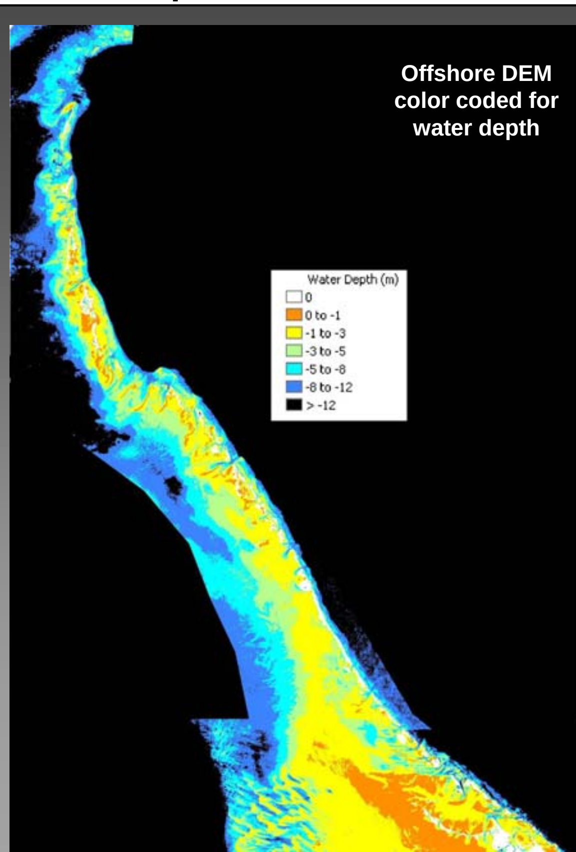
- The Exumas portion of Great Bahama Bank is an area of continuing interest to researchers in modern carbonates, an important training venue, and a valuable modern analog for understanding facies patterns in grainstone reservoirs.

- We hope to promote this interest by making readily available a set of processed satellite images, an onshore/offshore digital elevation model (DEM), and numerous examples of how this data can be visualized and used with an emphasis on better characterization and modeling of carbonate reservoirs.



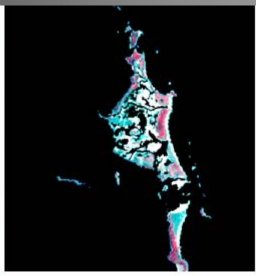
# Exumas GIS, Images and Maps



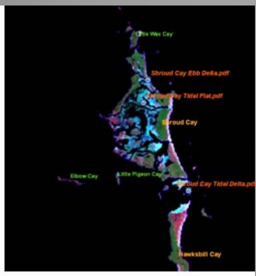




## Overview of satellite images, maps and enhanced DEM in the Exumas GIS

1984 Natural Color Landsat

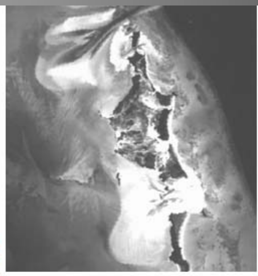


1984 onshore CIR Landsat



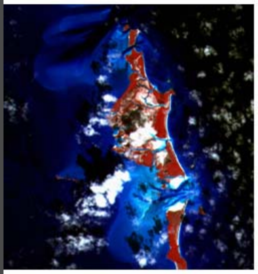
1984 Landsat with Locations and Reference Hyperlinks in GIS

1:31,250 Explorer Chart

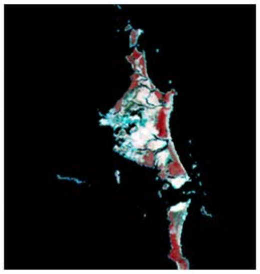


1984 Landsat Band 1 (reflected blue light used for bathymetry model)

Offshore 2-m contours derived from Band 1 DEM – land masked black



2002 typical CIR ASTER



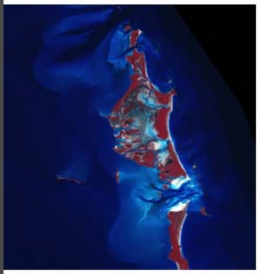
2002 onshore CIR ASTER

1984 Landsat Land Mask

1:25,000 Topographic Map (Bahamas LSD, 1969)

Space Shuttle (SRTM) DEM trimmed with Landsat land/water Mask

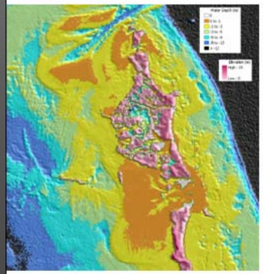
Onshore 2-m contours derived from Trimmed SRTM DEM



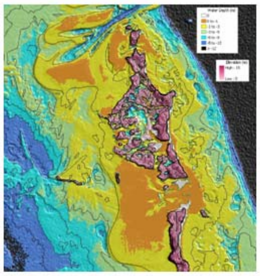
2005 typical CIR Quickbird

2005 Natural Color Quickbird

1984 Landsat Land-Water Boundary



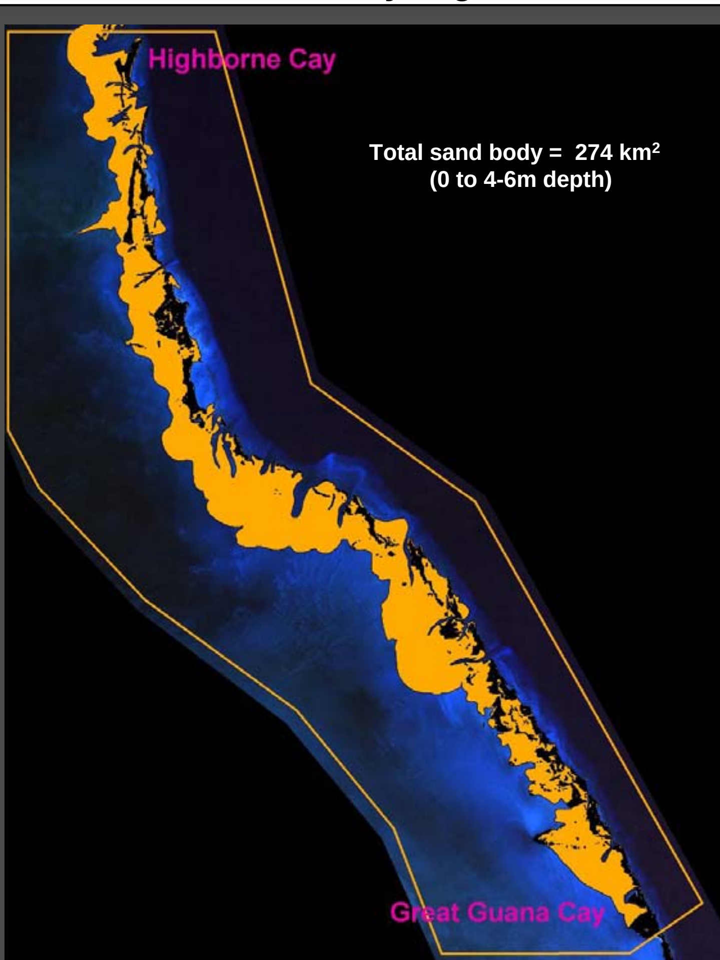
Offshore & Onshore DEMs illuminated from the NE and color-coded

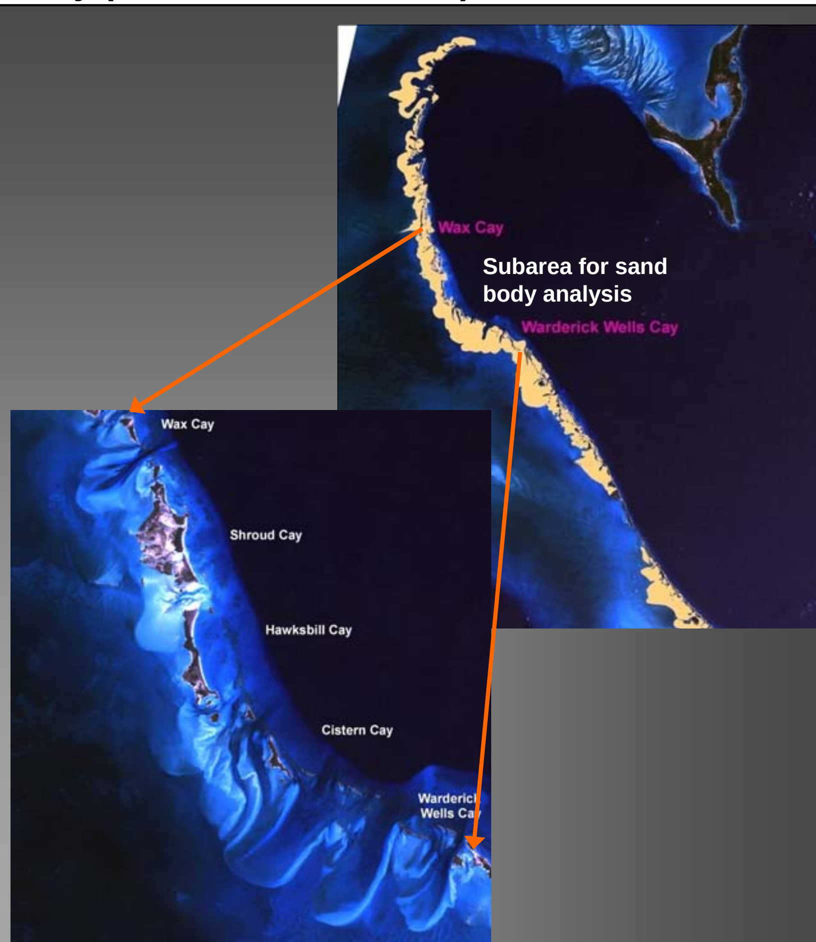


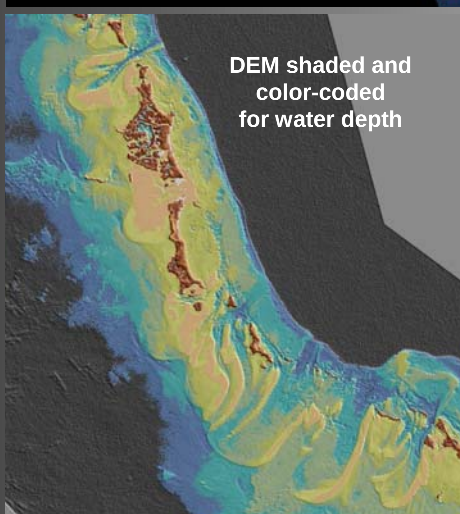
Offshore & Onshore DEMs illuminated and color-coded with derived contours

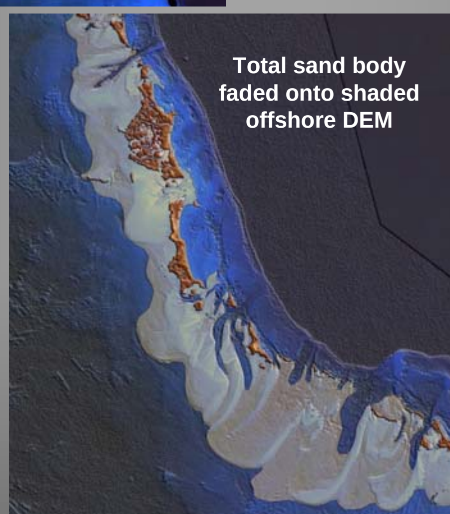
2005 Quickbird draped over shaded Offshore DEM

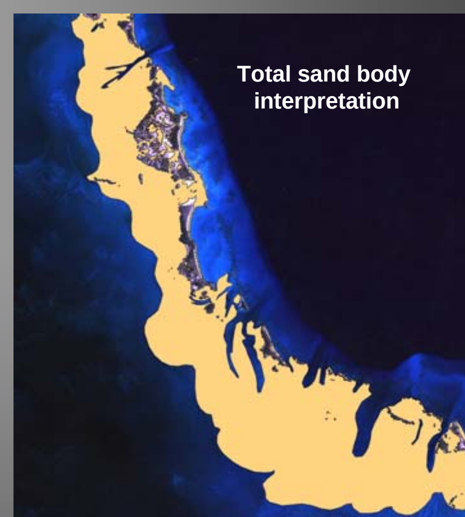
# Analyzing the Total Sand Body (= Potential Reservoir)

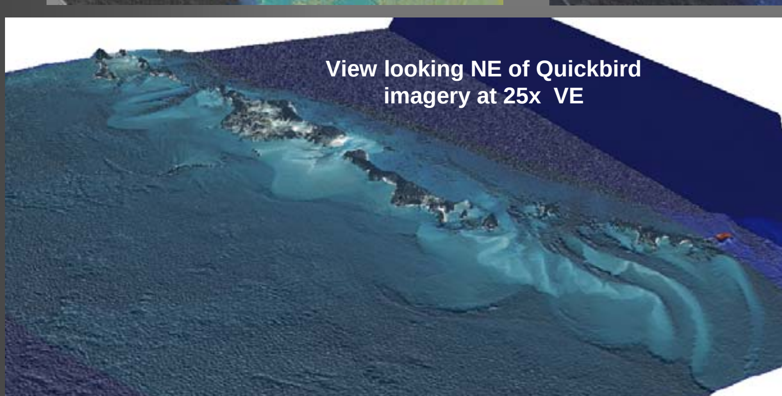


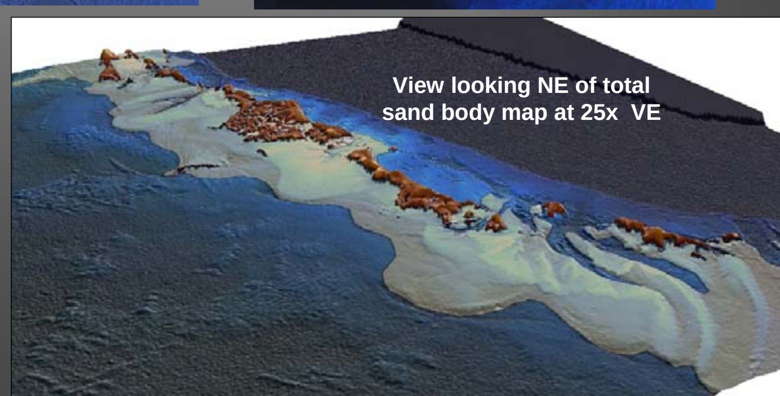



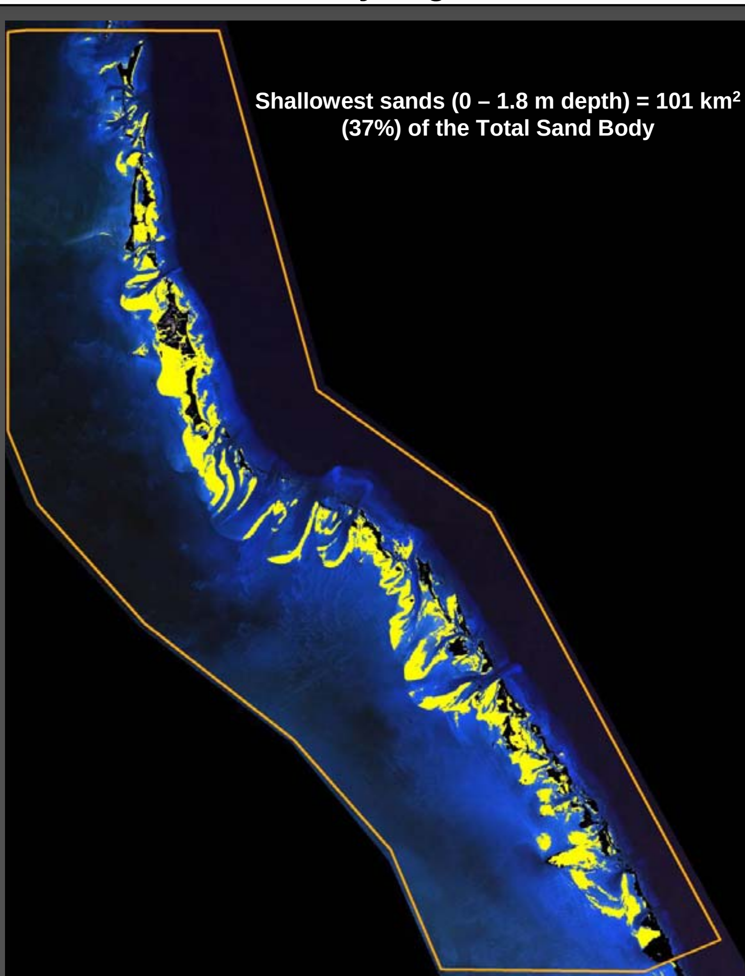



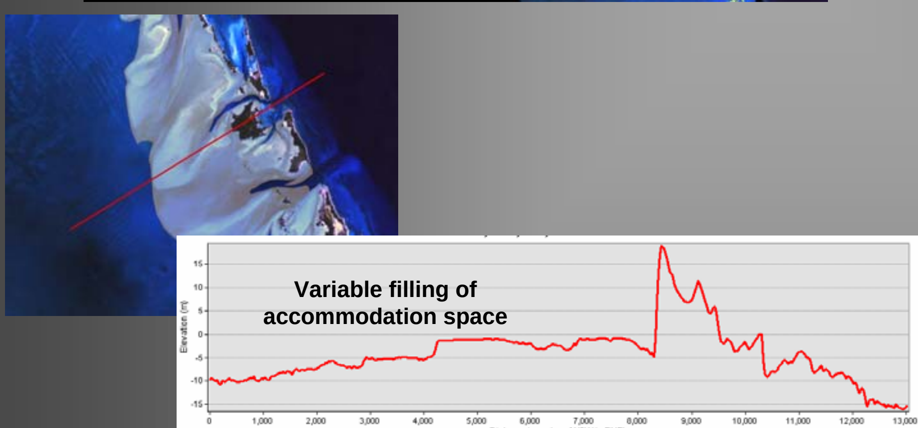



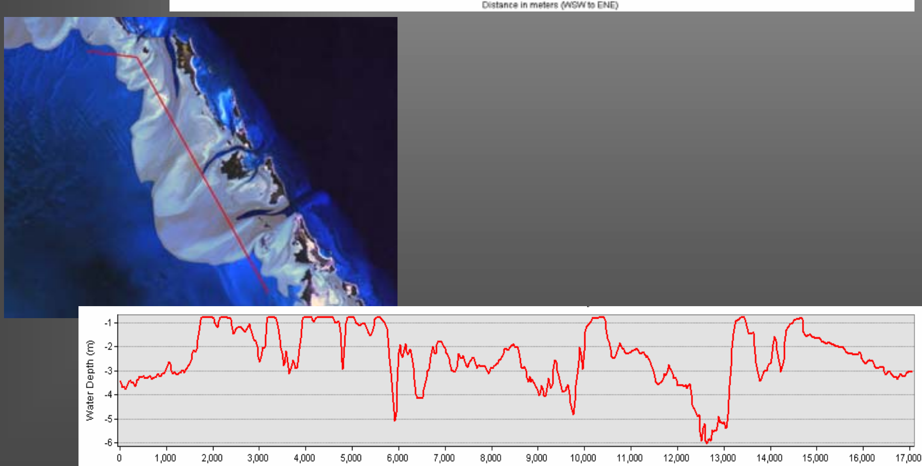



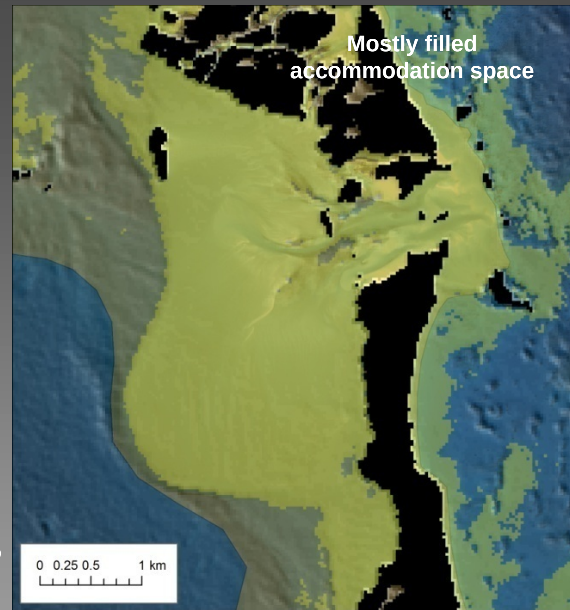
# Analyzing the Shallowest Sands (= Best Reservoir)

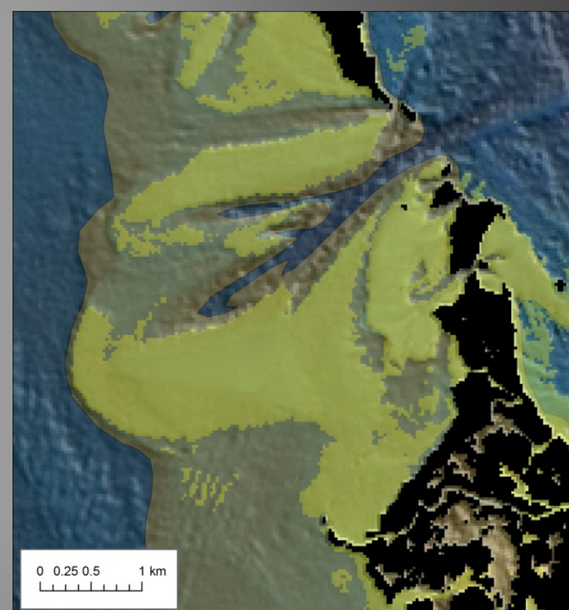


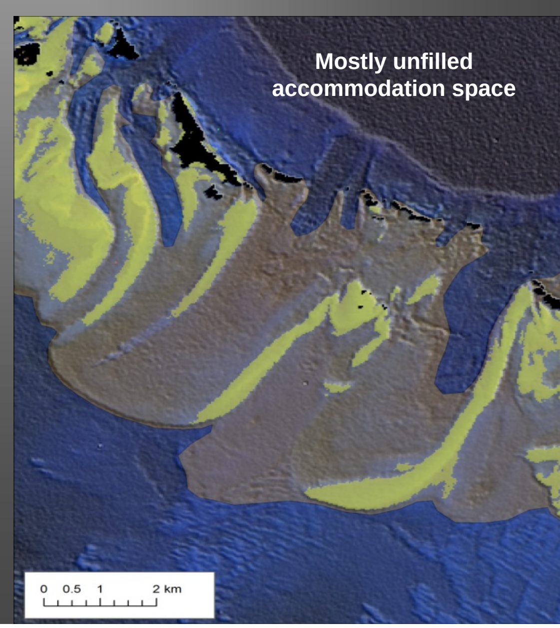



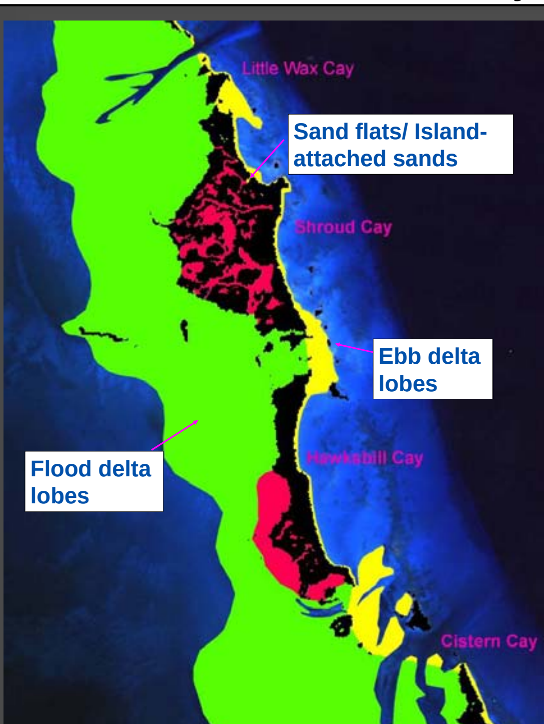

Shallowest sands (yellow) superimposed on total sand body map (gray) and Landsat image; islands shown as black.

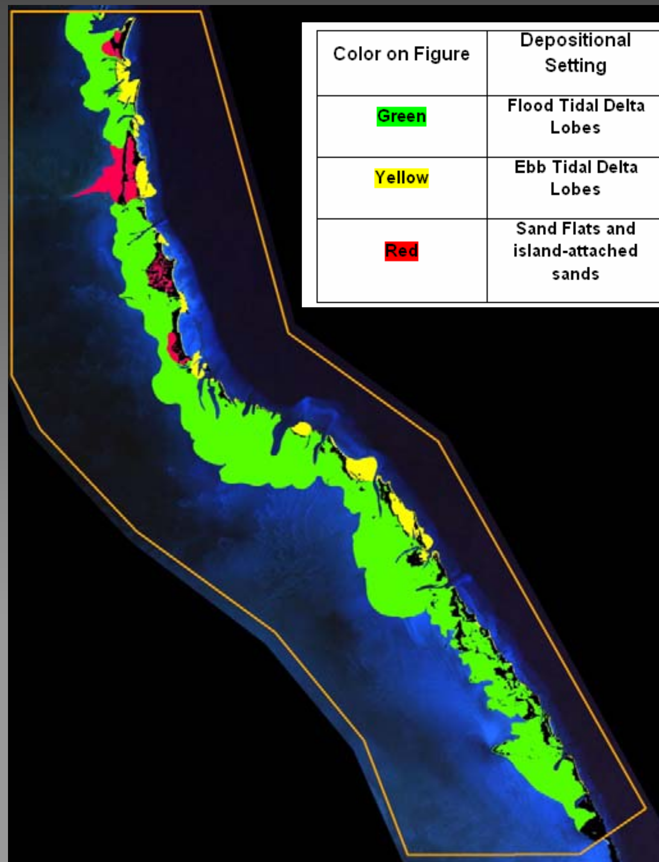


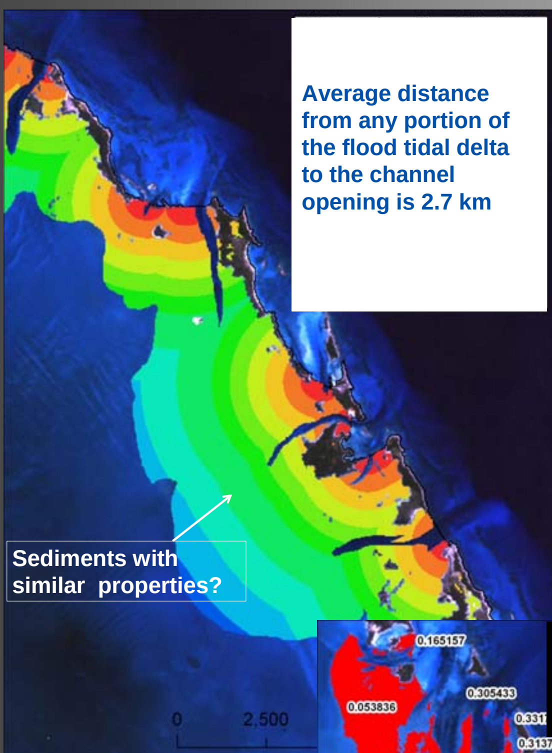
# Analyzing the Sand Body by Environment



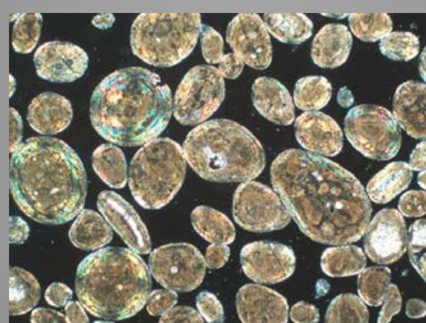



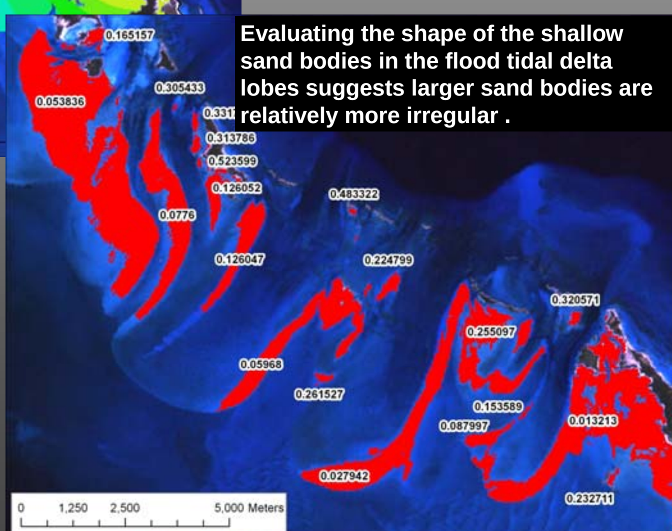
| Color on Figure | Depositional Setting | Area (km²) | Area (%) |
|---|---|---|---|
| Green | Flood Tidal Delta Lobes | 273.2 | 85.3 |
| Yellow | Ebb Tidal Delta Lobes | 29.6 | 9.2 |
| Red | Sand Flats and island-attached sands | 17.4 | 5.4 |

Flood tidal delta lobes comprise 85% of the total sand body

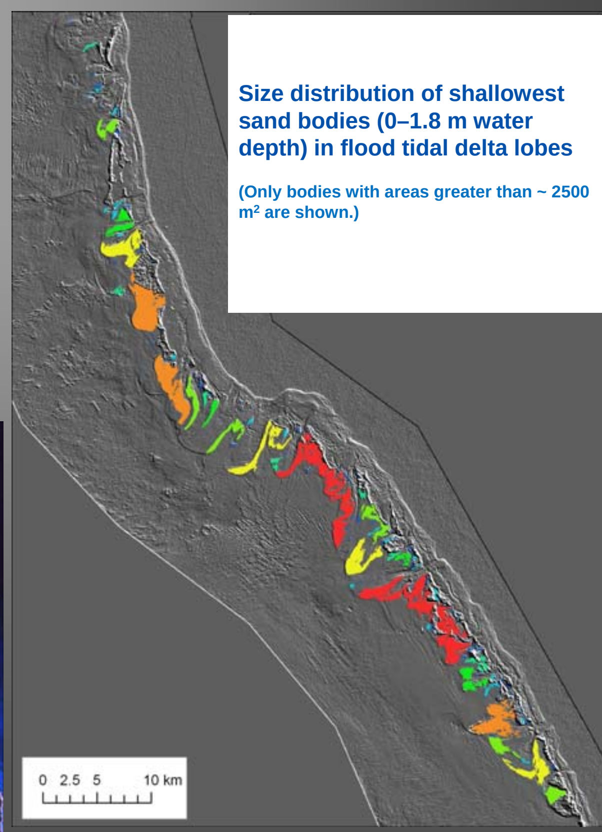



Average distance from any portion of the flood tidal delta to the channel opening is 2.7 km





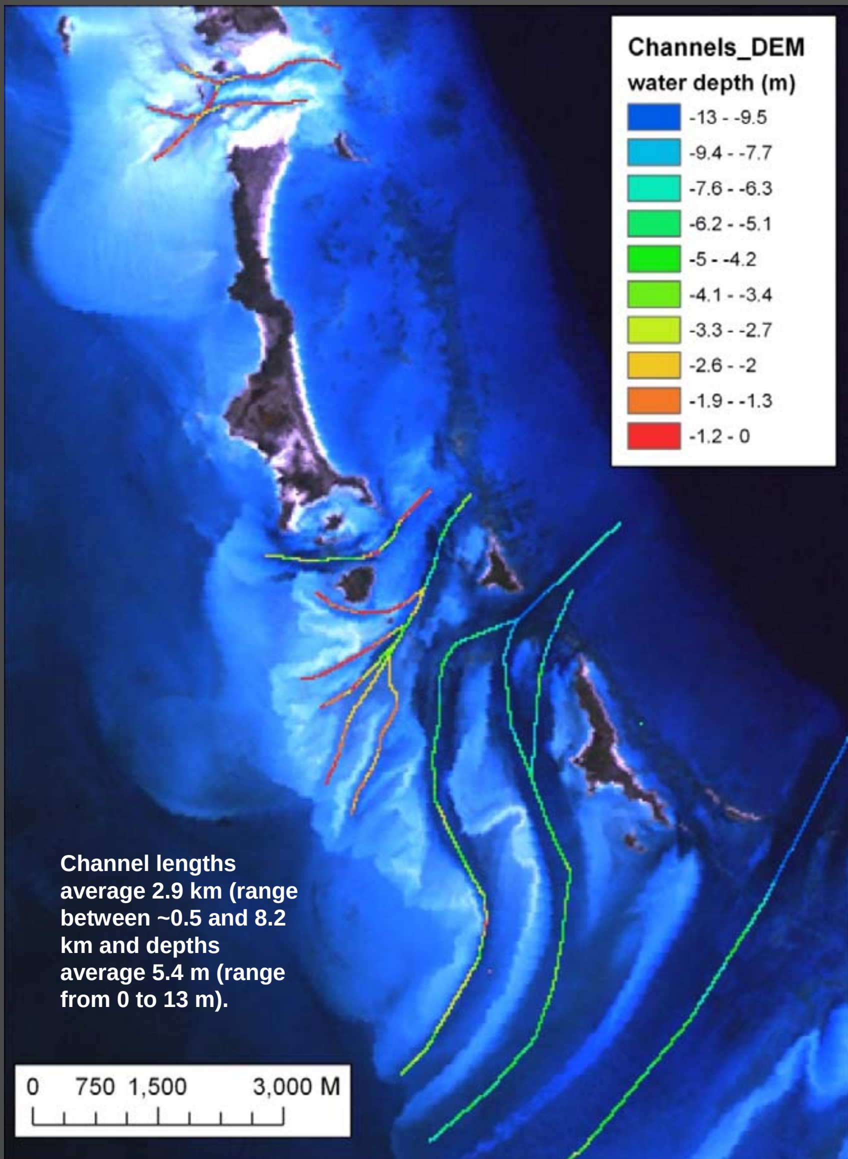

Evaluating the shape of the shallow sand bodies in the flood tidal delta lobes suggests larger sand bodies are relatively more irregular .

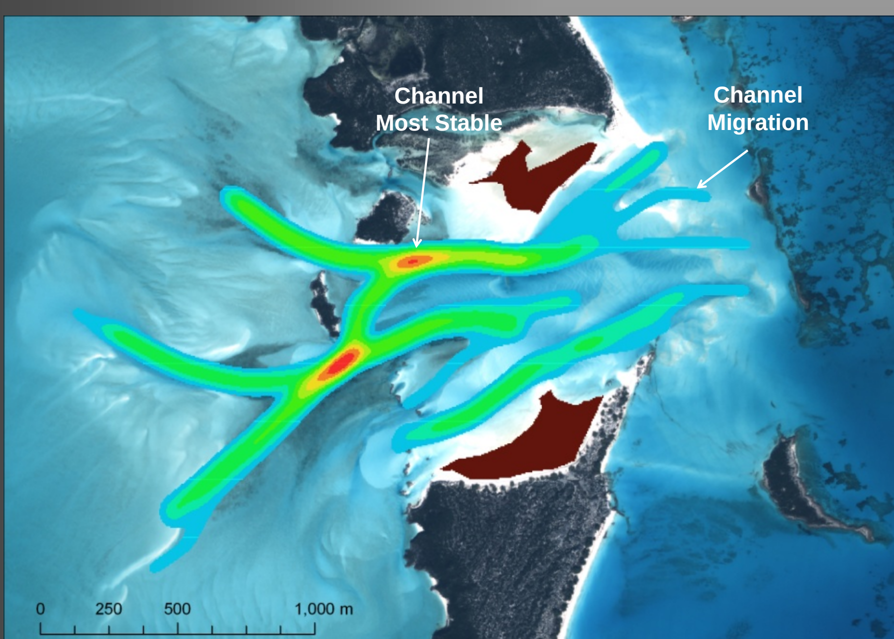



Size distribution of shallowest sand bodies (0–1.8 m water depth) in flood tidal delta lobes

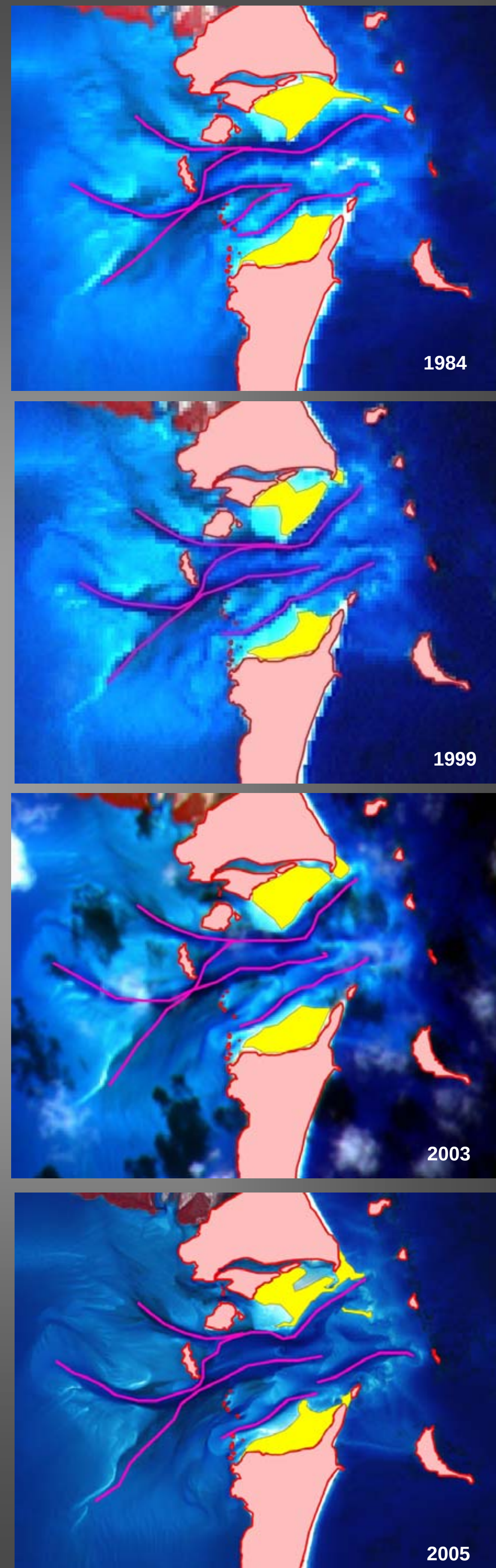
(Only bodies with areas greater than ~ 2500 m² are shown.)

# Analyzing Tidal Channels (= Potential Compartmentalization)

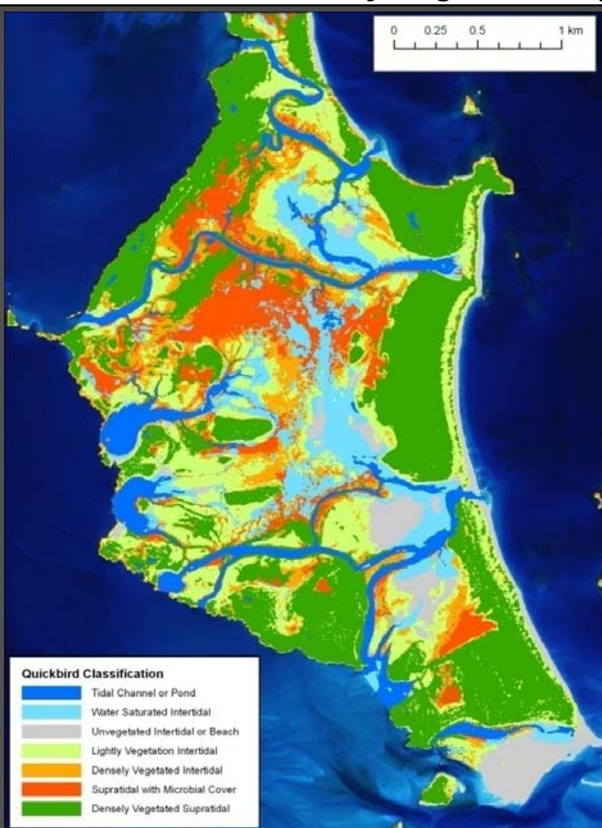



Changes in channels and emergent sand bars/beaches



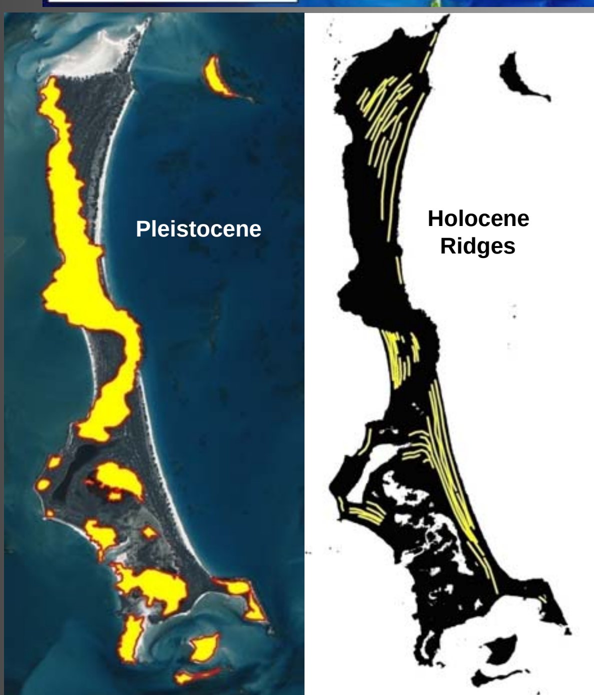
# Analyzing Islands (= Diagenesis & Heterogeneity)



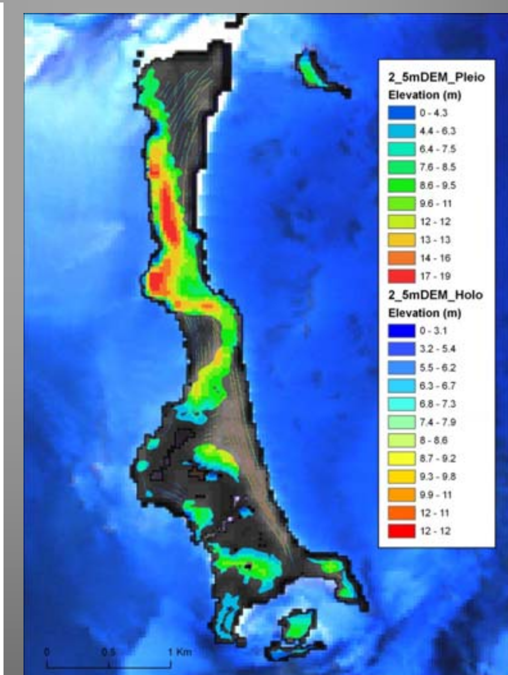

| | | Area ($m^2$ and %) | |
|---|---|---|---|
| Tidal Channel or Pond | Blue | 712,552 | 9.1 |
| Water Saturated Intertidal | Light Blue | 819,360 | 10.5 |
| Unvegetated Intertidal or Beach | Light Gray | 532,045 | 6.8 |
| Lightly Vegetation Intertidal | Light Green | 1,431,510 | 18.3 |
| Densely Vegetated Intertidal | Orange | 873,919 | 11.2 |
| Supratidal with Microbial Cover | Red | 759,842 | 9.7 |
| Densely Vegetated Supratidal | Green | 2,700,046 | 34.5 |
| TOTAL | | 7,829,274 | 100.0 |

Sand Flat Mapping Using Spectral Classification

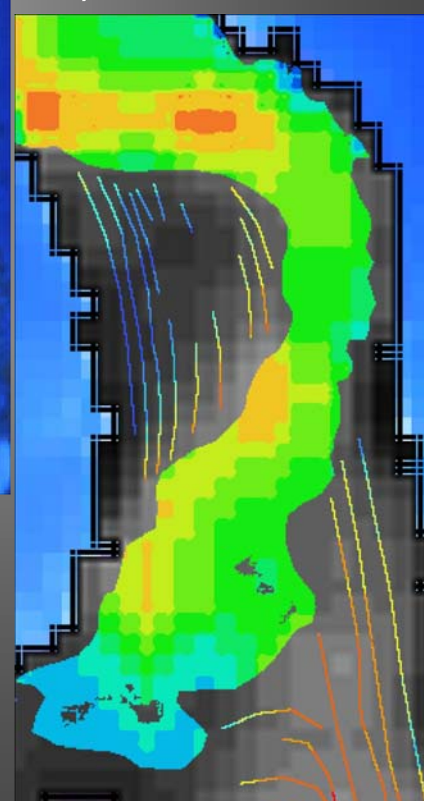
Analysis of Island Age




Analysis of Island Topography



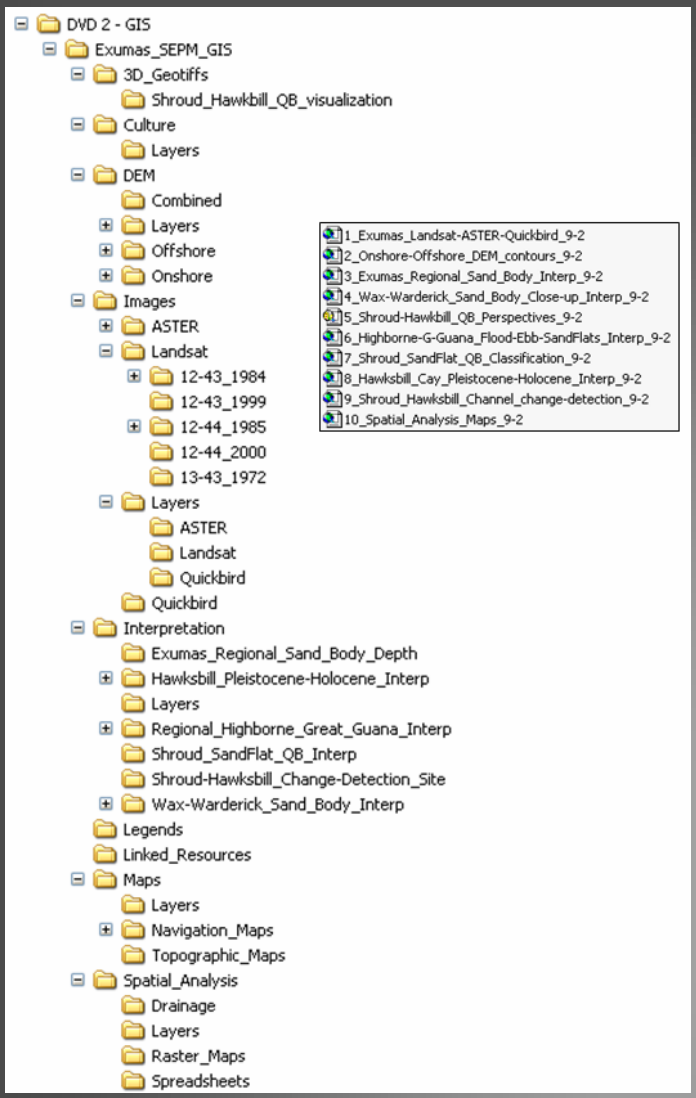

Holocene ridges have elevations from near sea level to 12 m (mean elevation of 7.7m) while Pleistocene landforms have elevations from near sea level to 19 m (mean elevation of 9.3m)



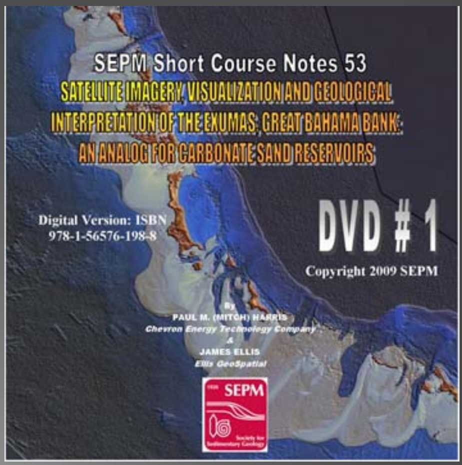
Pleistocene & Holocene Statistics

| Hawksbill Cay | |
|---|---|
| Land Area | 2.8 $km^2$ |
| Pleistocene | 1.07 $km^2$ (38%) |
| Holocene | 1.73 $km^2$ (62%) |
| Holocene Ridges | 17.6 km total length ; ~320 m average length |

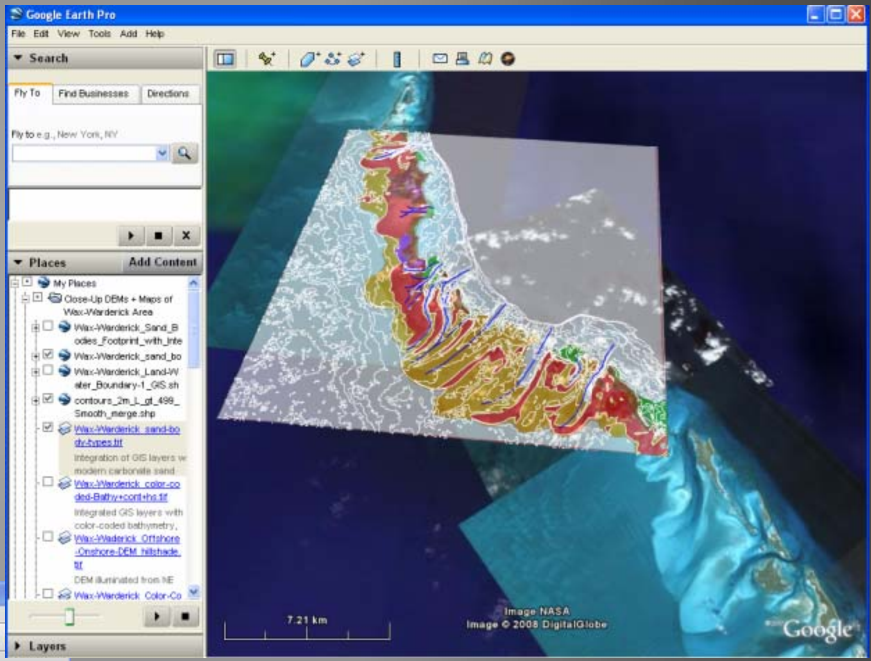
# Knowledge Transfer

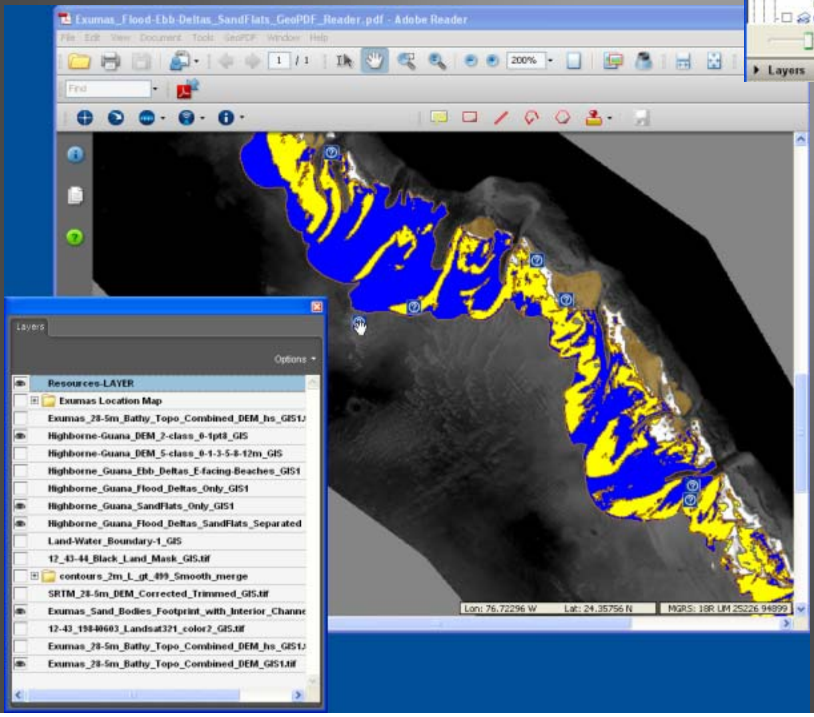



**Full-resolution satellite imagery and maps in GIS format (with ESRI ArcGIS 9.2 mxd and sdx project files), GeoPDFs, and GoogleEarth images are available as part of a digital publication from SEPM. The organization of the digital files is shown to the left.**



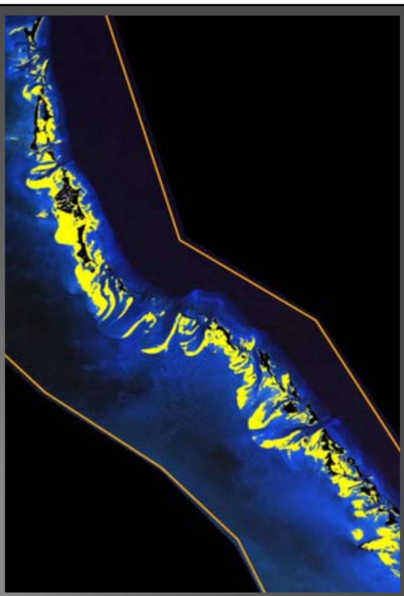

**A GIS layer transferred out of the GIS and displayed in GoogleEarth.**




**The GIS stack of geologic maps transferred out of the GIS and into Adobe Reader using GeoPDF, enabling image and map comparison, location, measurement, and interpretation to be done outside of GIS.**

## Summary Points



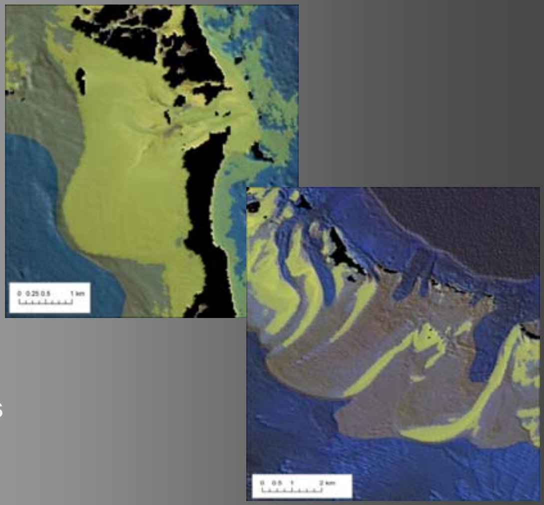
### Exploration-Scale Insight

- Exumas show spatial variability of depositional facies and early diagenetic overprint that create stratigraphic traps and reservoir heterogeneity

- A linear belt of mostly ooid sand, approximately 5-10 km wide and 170 km long, paralleling the platform and set back from the platform margin

- 37% of the sands are forming in the shallowest waters and would likely have the best reservoir quality

- The largest facies areally are flood tidal delta lobes extending several kilometers onto the platform

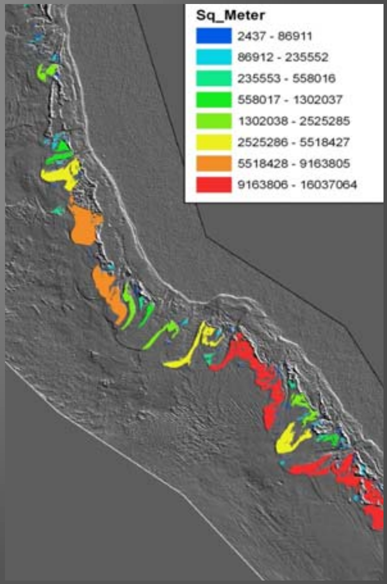


### Reservoir Heterogeneity Insight

- Small-scale patterns of heterogeneity are controlled by islands and tidal channels and their influence on the focusing of tidal and wind energy

- Where islands and channels are complex, bankward-directed lobes of sand are not uniform in their development and have their shallowest portions as sinuous, linear features

- Elsewhere, the islands and channels are more regular and the active shoals between are organized into better-formed and more uniformly shallow flood tidal deltas




### Reservoir Modeling Insight

Quantitative relations like the following are essential for building facies-based models:

- Shallowest sands comprise 37% of the total sand body
- Larger deposits of “shallowest sands” are up to ~8 $km^2$
- Larger sand bodies are more irregular in shape than smaller ones
- Flood tidal delta lobes represent 85% of the total sand body
- 52% of the shallowest sand bodies have areas greater than ~2500 $m^2$ and 8% are larger than 100,000 $m^2$
- These largest deposits are highly sinuous and maintain connectivity
- Tidal channels, which may potentially isolate or compartmentalize reservoir zones, average 2.9 km in length