

Facies Trend Metrics of Modern Carbonate Depositional Systems*

By

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Search and Discovery Article #50081 (2008)

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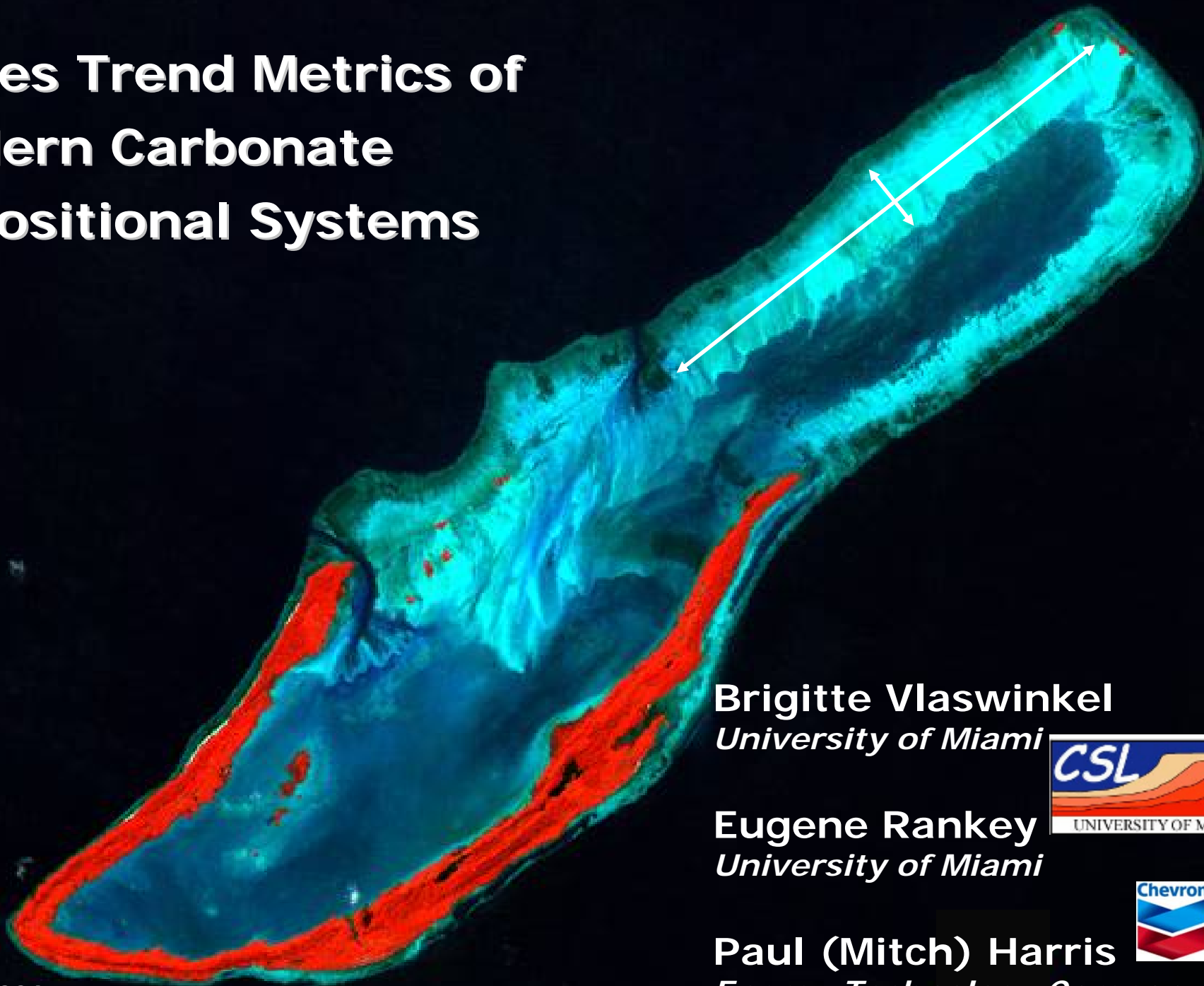
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Abstract

An accurate facies model is essential for realistic reservoir modeling, as depositional facies can be a main parameter controlling heterogeneity in porosity and permeability. Prediction of the quantitative attributes (size, shape, orientation, distribution, etc.) and variation of facies dimensions are also required for enhanced Multiple Point Statistics simulations for carbonate systems. To address these needs, we generated quantitative data on sizes and shapes of facies within and among different sized and shaped platforms. Landsat images from 19 modern carbonate platforms are used as analogs to offer insights into potential facies heterogeneity of carbonate systems and reservoirs.

The workflow for identifying and quantifying attributes of facies tracts included integrating literature and remote sensing images in a GIS, followed by statistical analysis. Based on objective reproducible criteria, up to 9 different facies classes were mapped and hand-digitized on all platforms, using an image analysis software program. A GIS provided a tool for quantitative characterization, measuring for every polygon of each facies attributes, such as area, perimeter, width, length, orientation, and the variability (mean, max, min) within those metrics. Subsequent statistical analyses demonstrate the existence of certain predictive “rules” between the configuration and composition of facies tracts on and among carbonate platforms (e.g., size of platform and number and abundance of facies and size of platform and shape complexity.) These kinds of “rules” provide both general concepts and raw data that can be used as input for enhanced carbonate models.

Facies Trend Metrics of Modern Carbonate Depositional Systems



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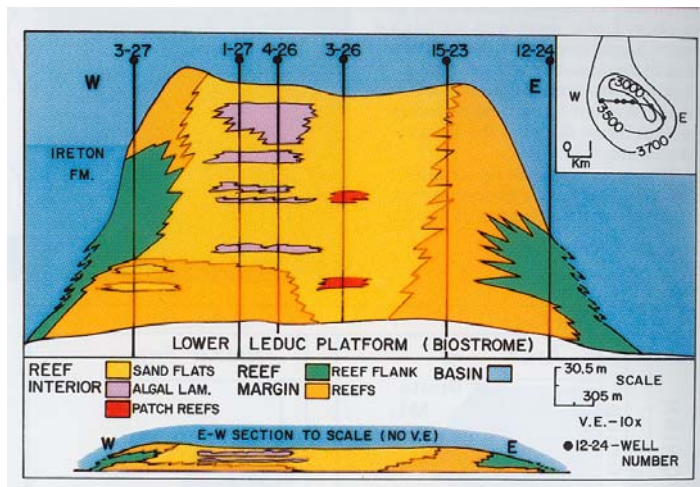


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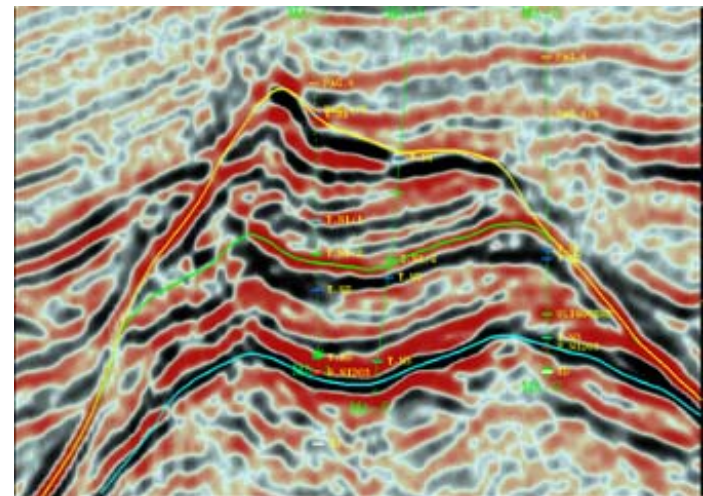


Significance from a subsurface perspective

- >40% of the world's oil and gas reserves come from reservoirs in carbonate rocks
- Isolated carbonate platforms are common
- Reefs and associated facies can be important components



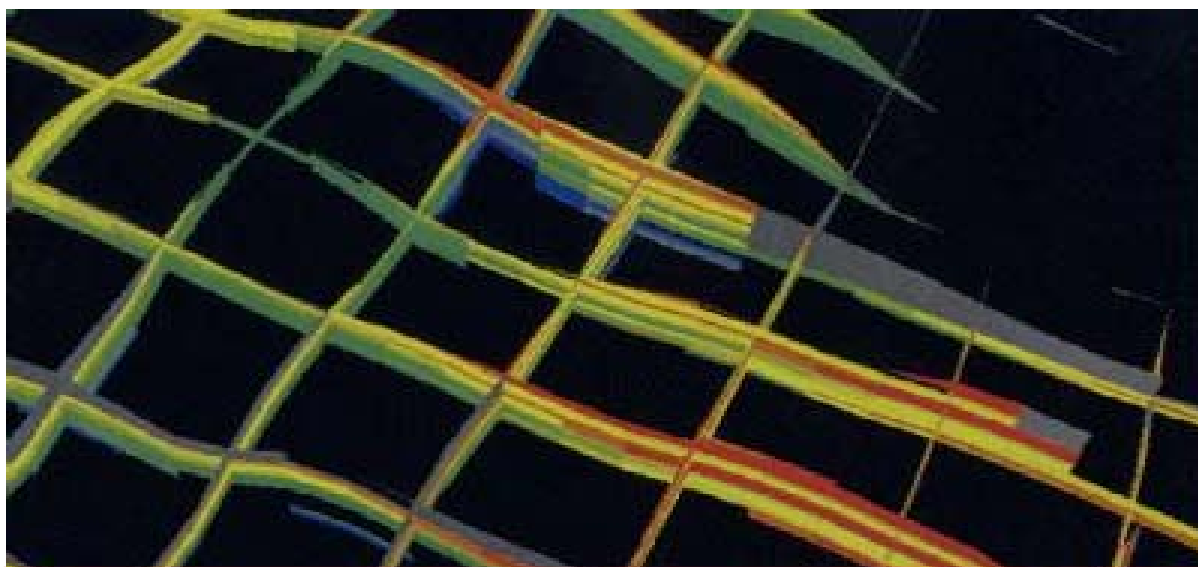
Golden Spike Alberta - Walls, 1983



Malampaya - Grötsch and Mercadier, 1999

Modern Reefs as **2D** Templates for Ancient Reefs

Main objective: quantitative data collection from satellite images for conceptual facies model



Prediction of quantitative attributes (size, shape, distribution) and variation of facies dimensions to drive enhanced geologic modeling for carbonate systems

Rules?



Quantify



Predict

Aims

- Provide an overview of the **spectrum of facies patterns** present in modern isolated carbonate systems
- Obtain **quantitative data** on facies dimensions, grouped by **size and shape** of carbonate platform
- Explore **correlations and trends** on landscape and facies scale

Key points

- General landscape rules across platform top
- Trends for reef belt facies represent predictive tools

Limitations

■ 'Snapshot'

- *Two-dimensional, remote sensed data*
- *Minimal ground-truthing*

■ Not all-inclusive

- *19 datasets is just a start...*
- *Only one type of carbonate platform*
- *Not all facies are well-covered in dataset*

■ Arbitrary (size and shape) grouping of platforms

still....important step in gathering much needed quantitative data!

Outline

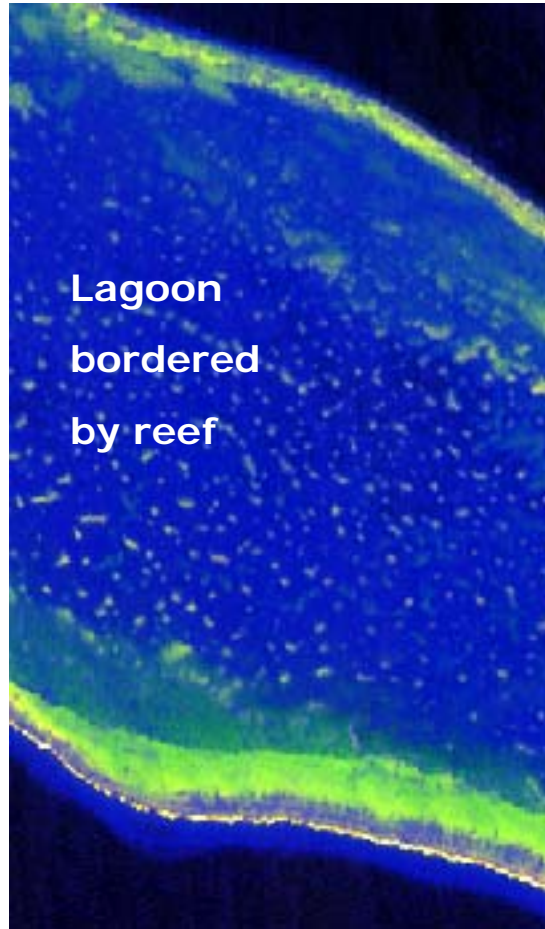
- Introduction
- Workflow
 - 1. Define objective reproducible criteria
 - 2. Group facies
 - 3. Satellite image processing
 - 4. ArcGIS processing
- Data
- Results
 - General landscape rules
 - Reef facies metrics
- Conclusions

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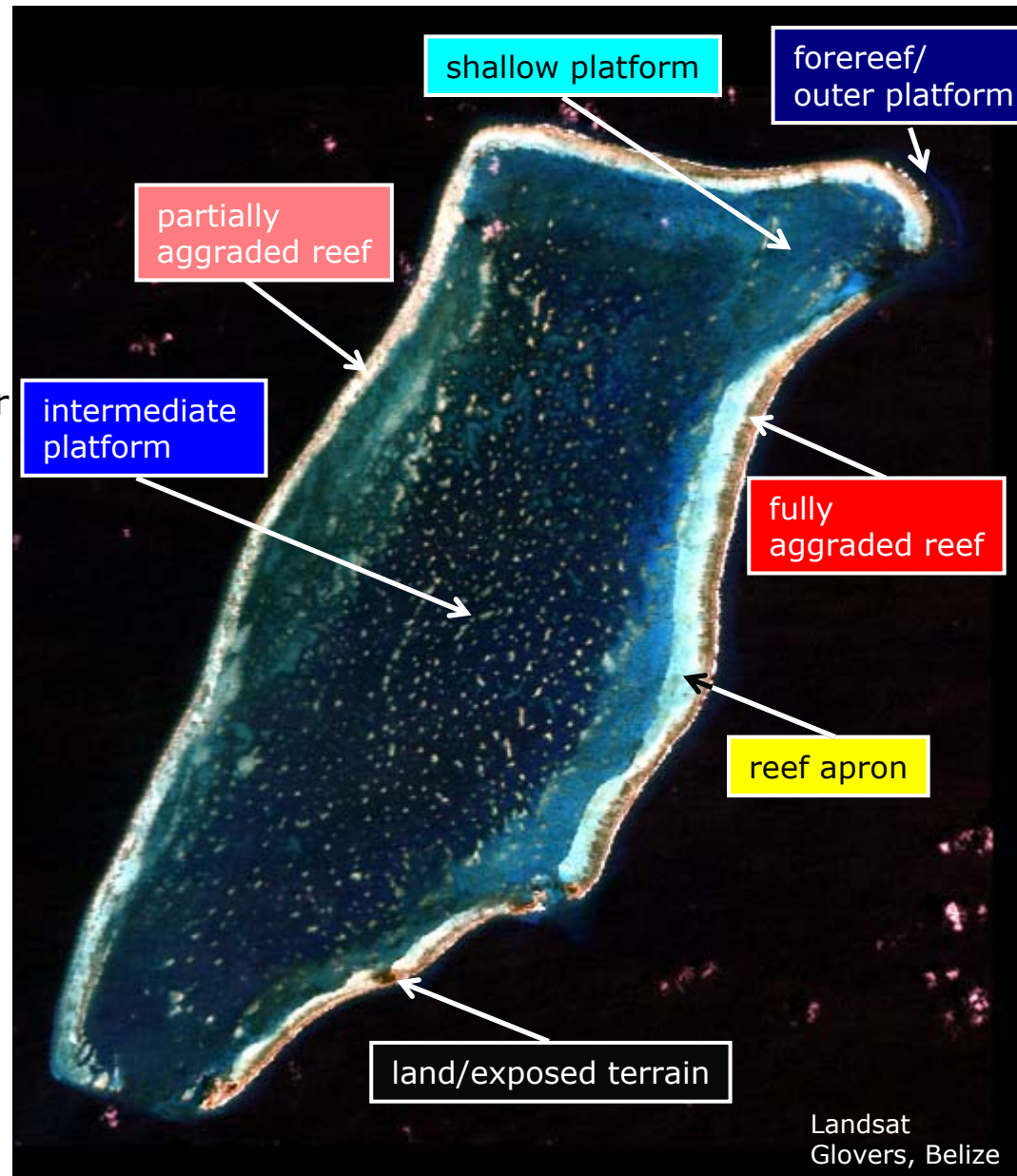
Objective Reproducible Criteria for Facies Mapping

- Color
- Texture
- Shape
- Context



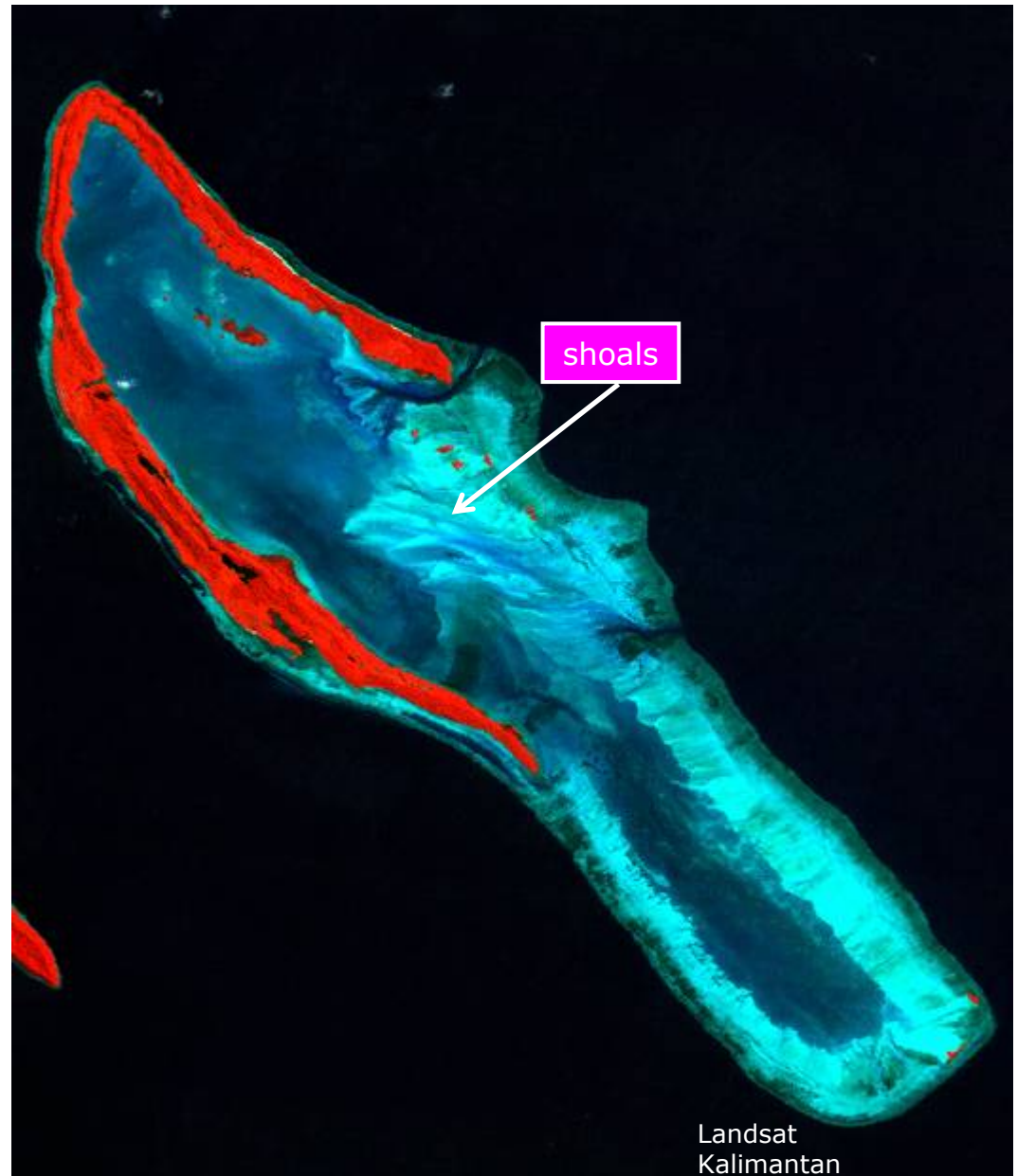
Depositional Facies – Landsat 5 and 7

1. Fully aggraded reef
2. Partially aggraded reef
3. Reef apron
4. Shallow platform interior (w or w/o isolated reefs)
1. Intermediate platform interior (w or w/o reefs)
2. Forereef/outer platform
3. Land/exposed terrain
4. Shoals
5. Deep platform interior (w or w/o reefs)



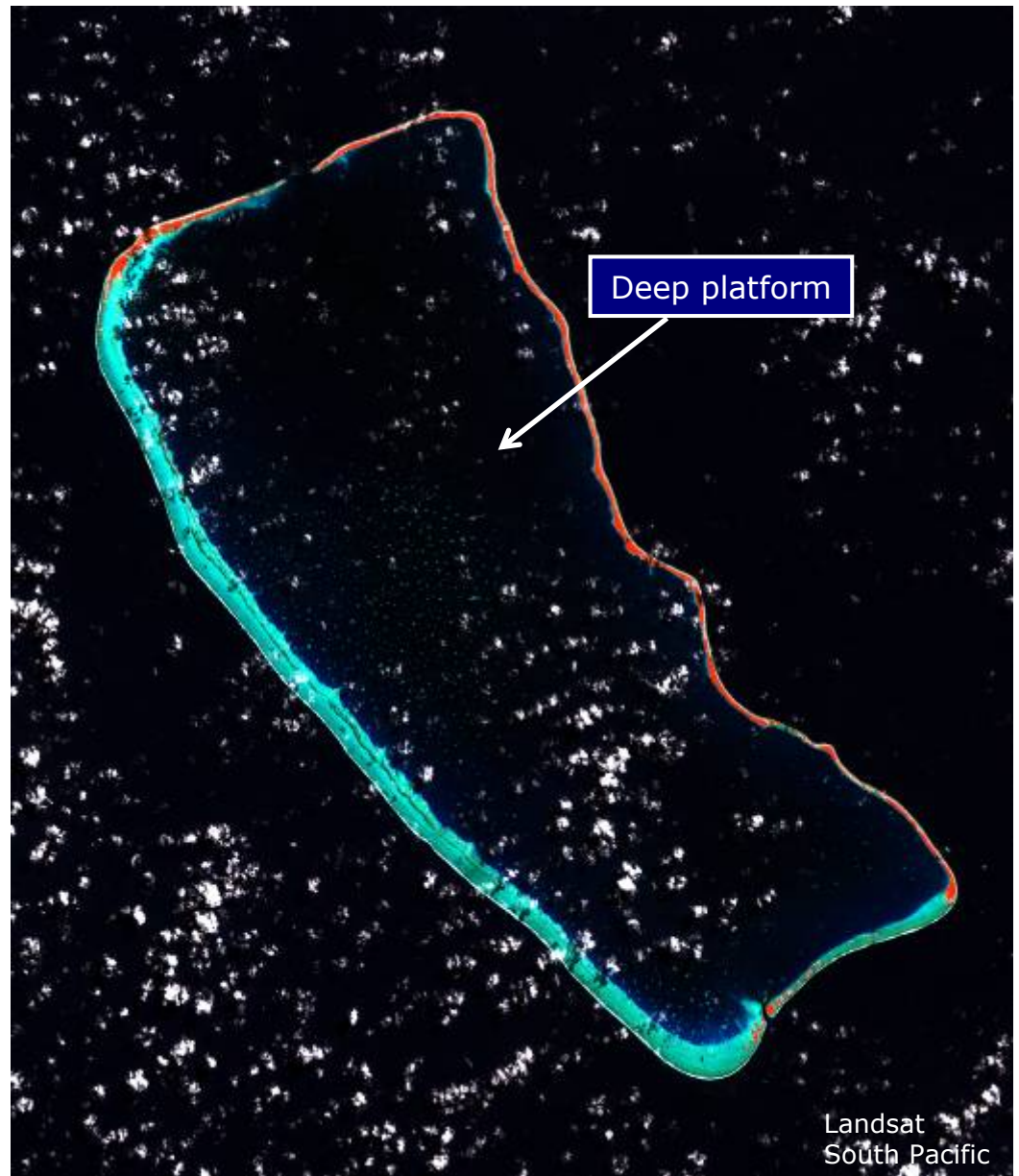
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8. **Shoals**
9. Deep platform interior (w or w/o reefs)



Depositional Facies

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9. **Deep platform interior (w or w/o reefs)**



'Reservoir' Facies

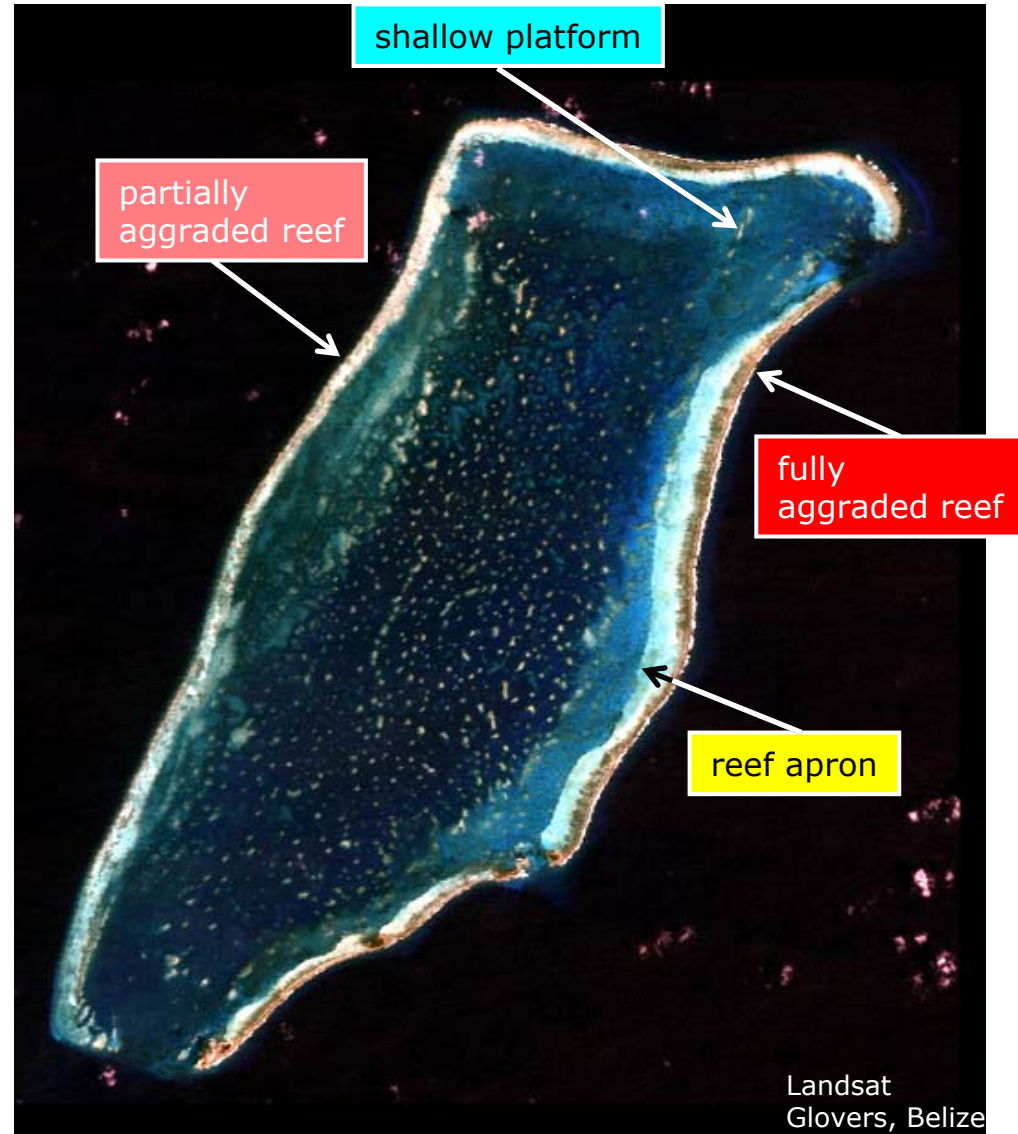
Fully aggraded reef

Partially aggraded reef

Reef apron

Shoals

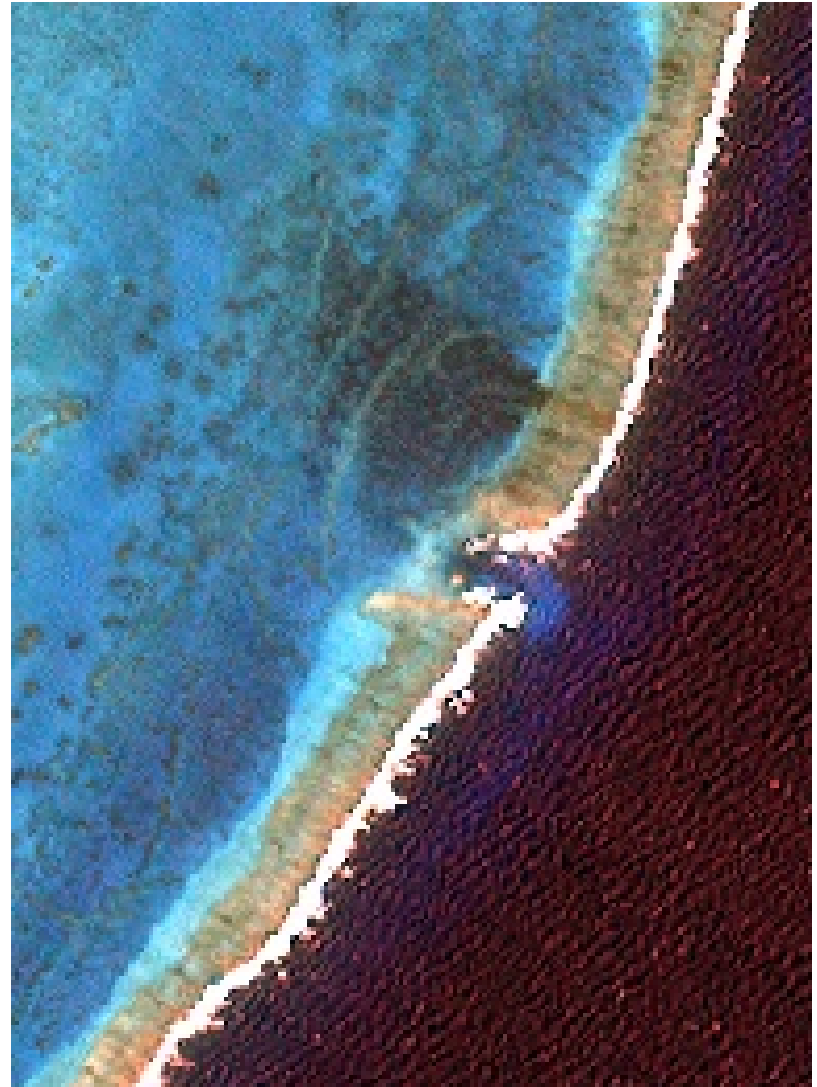
Shallow platform interior



Fully Aggraded Reef

- Homogeneous: combination of bands 1,2,3: honey-brown feature
 - Orientation of long axis parallel or near platform break
 - Breaking waves sufficient but not necessary
 - 'Striations' perpendicular to platform edge
- Includes reef crest, reef flat, back reef

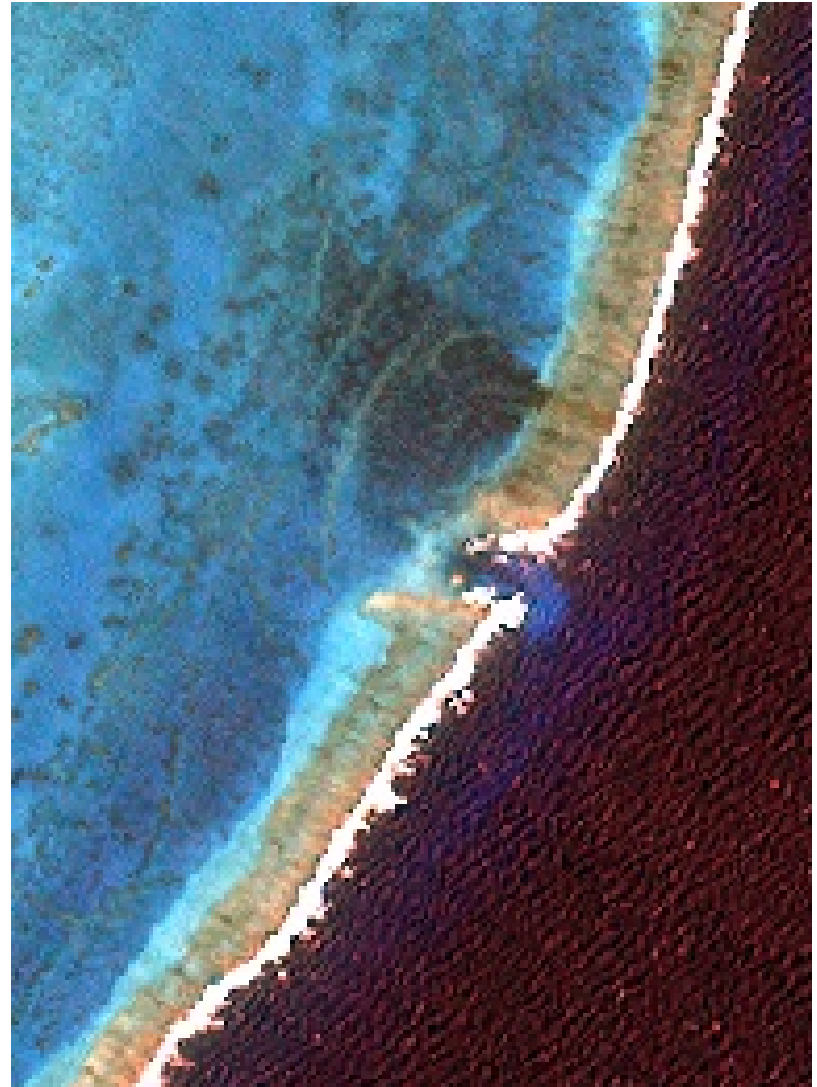
Rock type: boundstone



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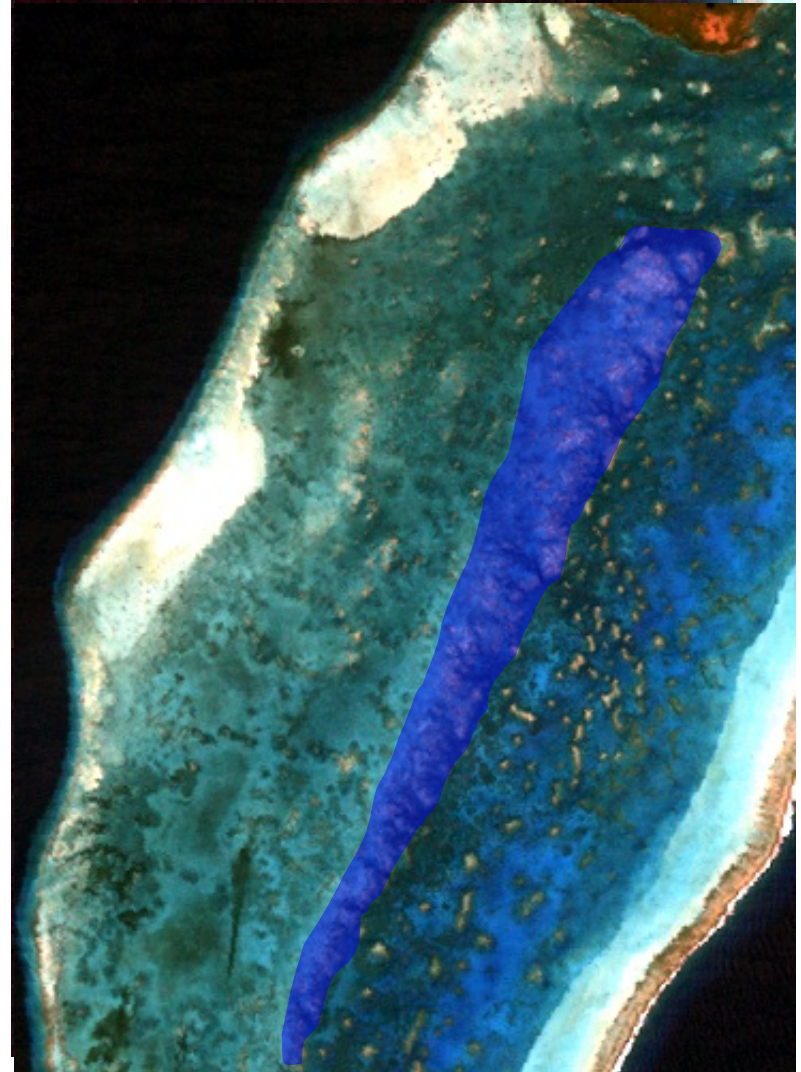
Rock type: boundstone



Partially Aggraded Reef

- Heterogeneous: Combination of bands 1,2,3: mix of honey-brown features with bright patches
- Linear coalescence of patchy honey-brown texture
- Orientation of long axis parallel to platform break
- Location not restricted at or near platform break (occurs also in platform interior)

Rock type: boundstone and skeletal grainstone



Reef Apron

- Combination of bands 1,2,3: highly reflective, homogeneous white color
 - Always platform-ward of reef (fully or partially aggraded)
 - Long axis parallel to reef
- Bare reef derived sand

Rock type: skeletal grainstone



Shoals

- Bedforms are visible
 - Combination of bands 1,2,3:
highly reflective, white color
- Reworked skeletal or oolitic sands
- Active or stabilized

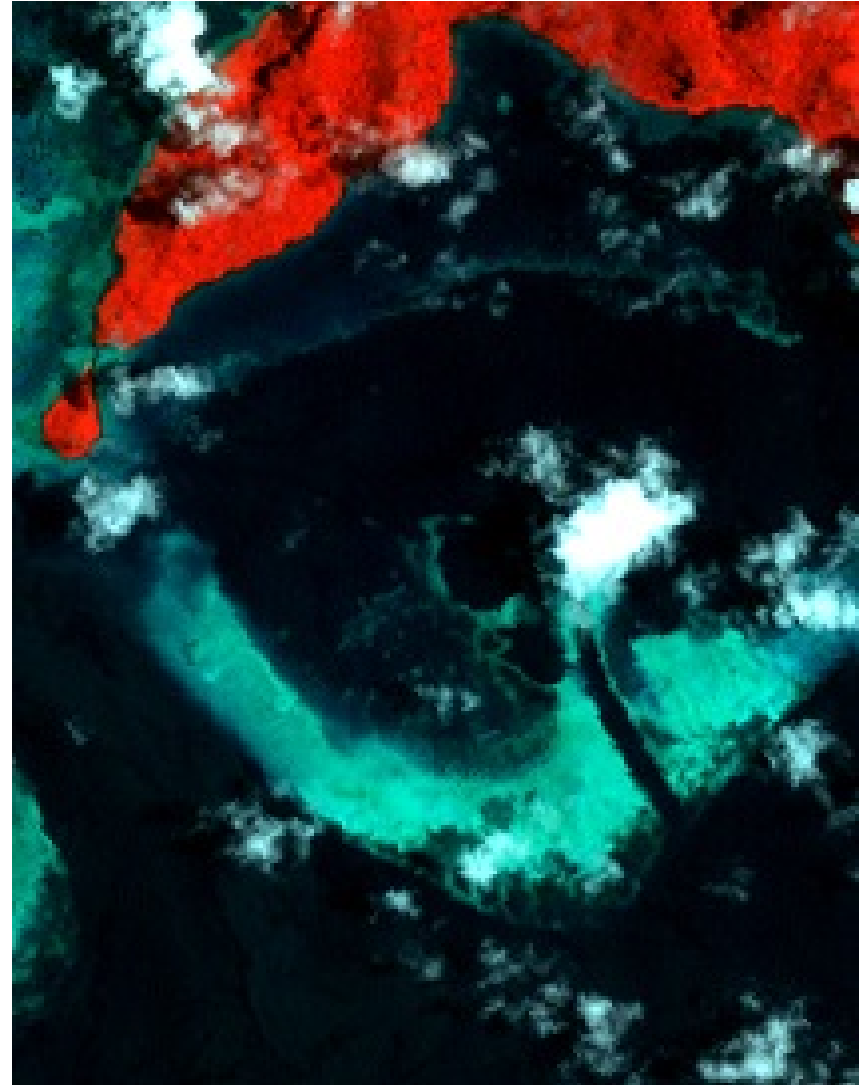
Rock type: grainstone



Shallow Platform Interior Without Reefs

- Texturally homogeneous
 - Combination of bands 1,2,3: highly reflective, turquoise
 - Absence of bedforms and reefs
-
- Can be seagrass covered
 - Can be more sandy than muddy
 - Shallow water depth (< 3 m)

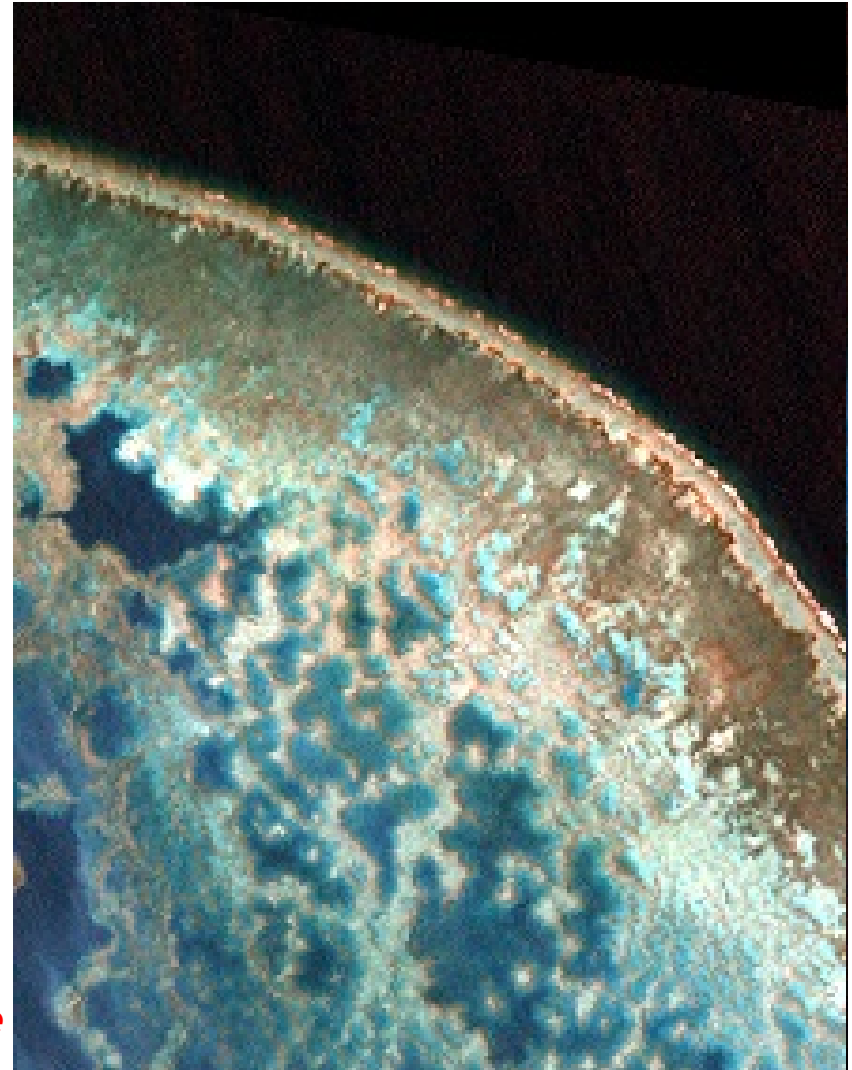
Rock type: wackestone -packstone



Shallow Platform Interior With Reefs

- Heterogeneous: combination of bands 1,2,3: highly reflective, turquoise with honey brown features
 - Honey brown features have patchy texture
 - Reefs can be circular, elongate or anastomosing
-
- Can be seagrass covered
 - Can be more sandy than muddy
 - Shallow water depth

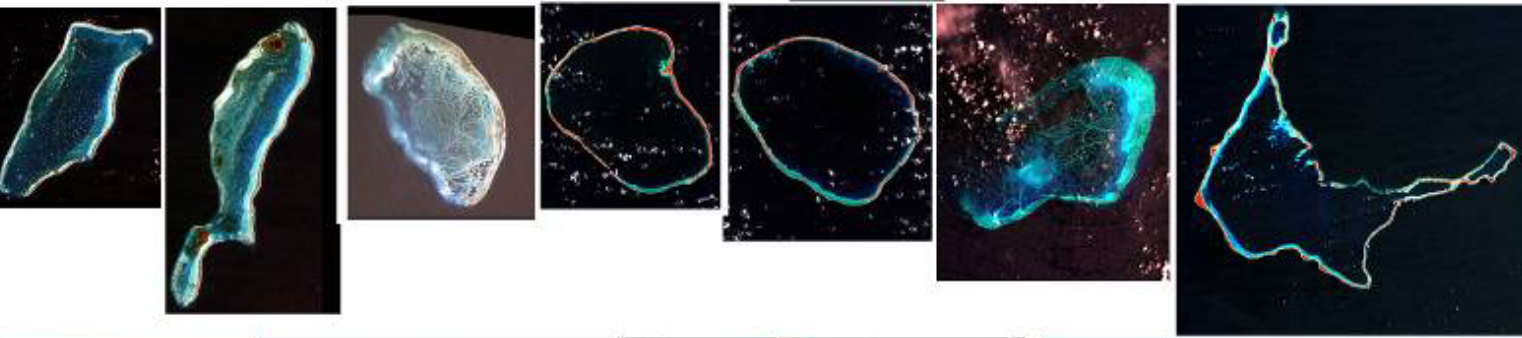
Rock type: wackestone - boundstone



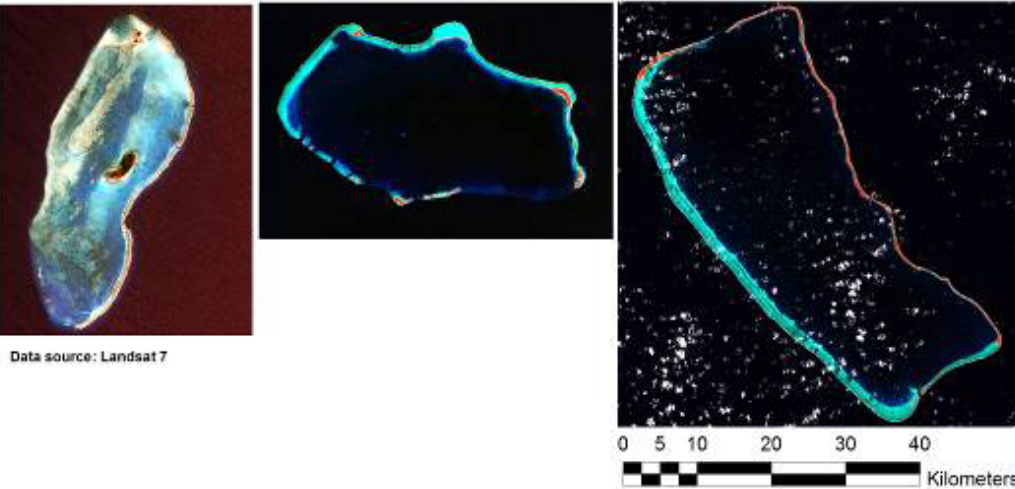
Modern Platforms Sorted by Size



Small
32-177 km²



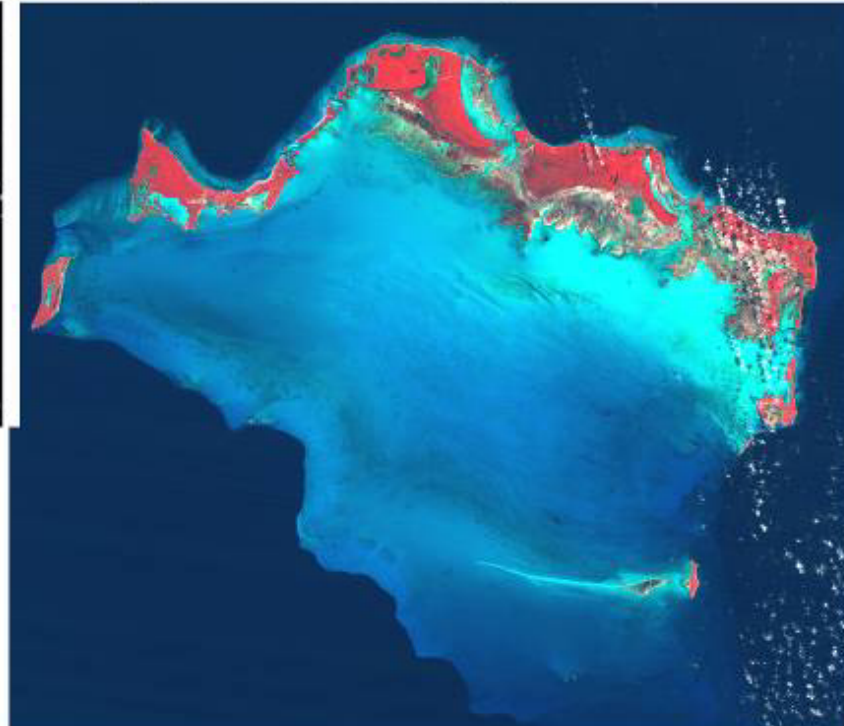
Intermediate
254-445 km²



Data source: Landsat 7

Large
604-6167 km²

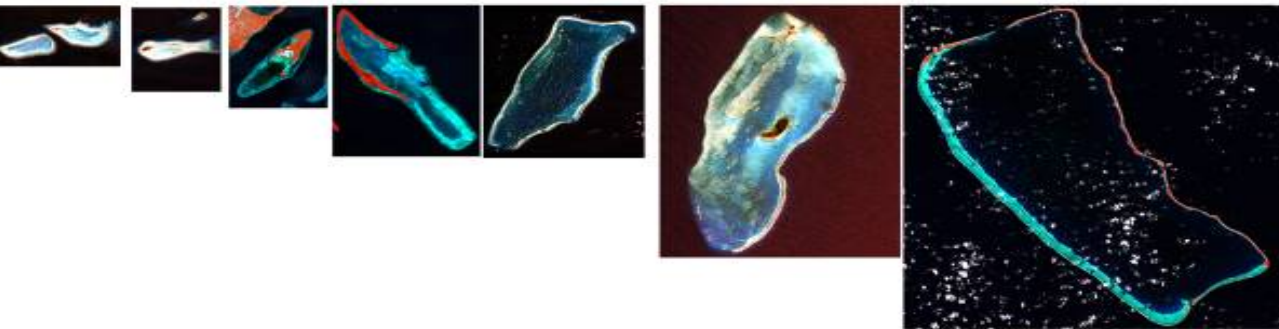
Size is a continuous variable with arbitrary breaks....



Modern Platforms Sorted by Shape



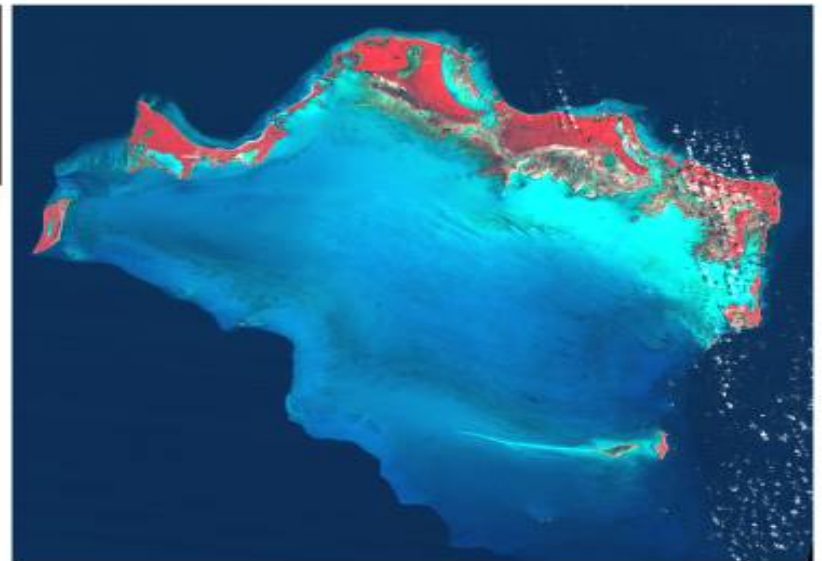
Circular



Elongate



Irregular



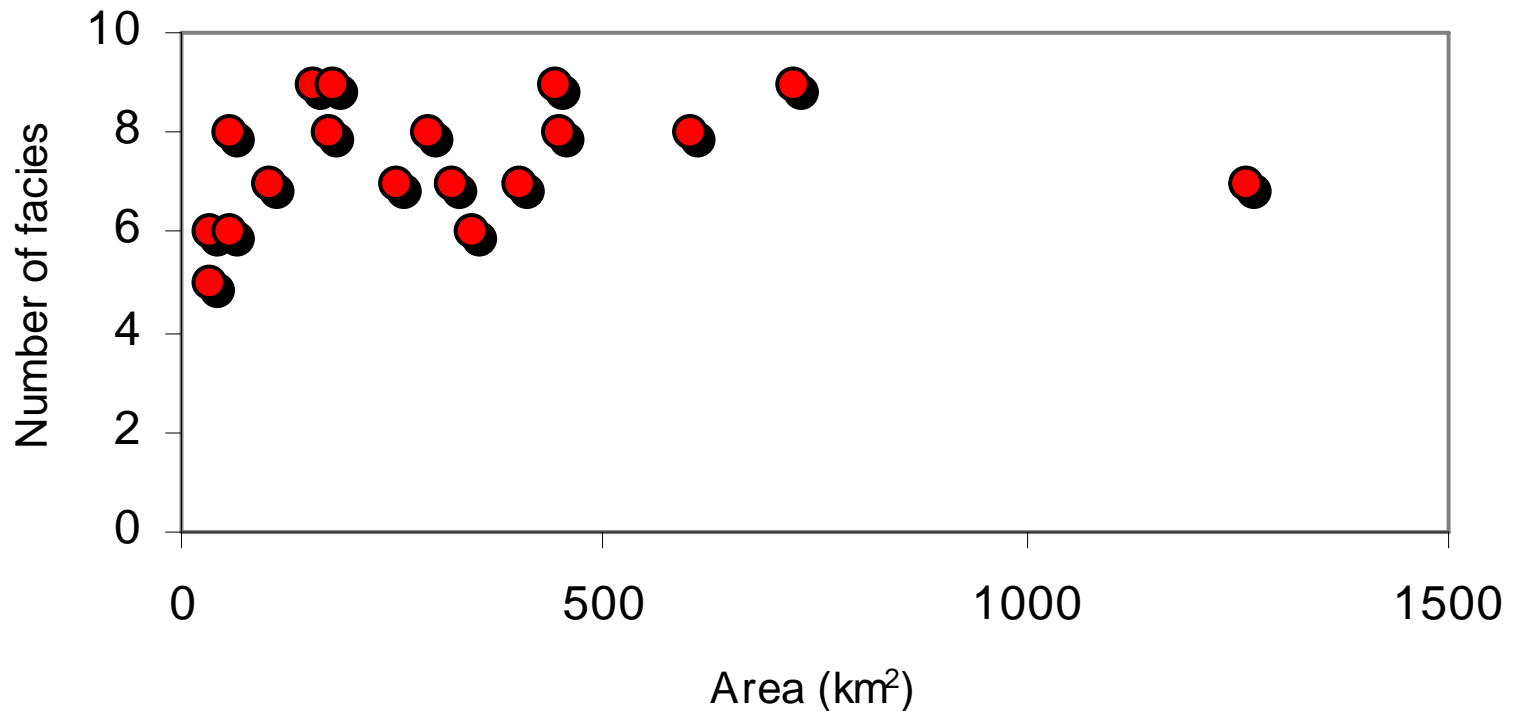
Shape is a continuous variable with arbitrary breaks....



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 - **General landscape rules**
 - Reef facies metrics
- Conclusions

Platform Size and Number of Facies

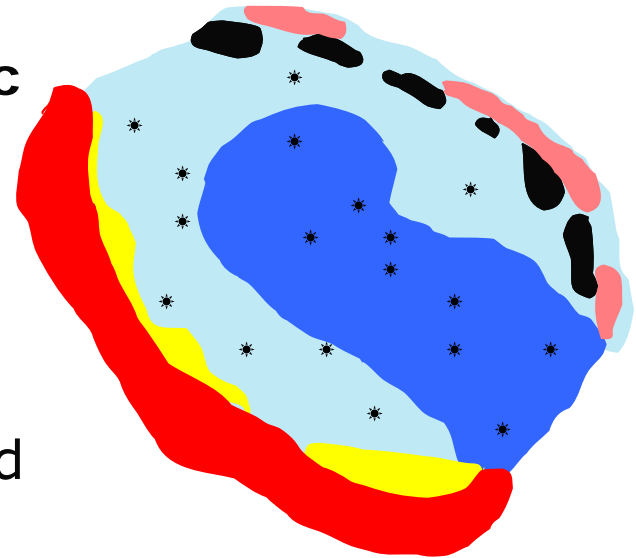


Number of facies is independent of platform size
Average # of facies: 7-8

Platform configuration

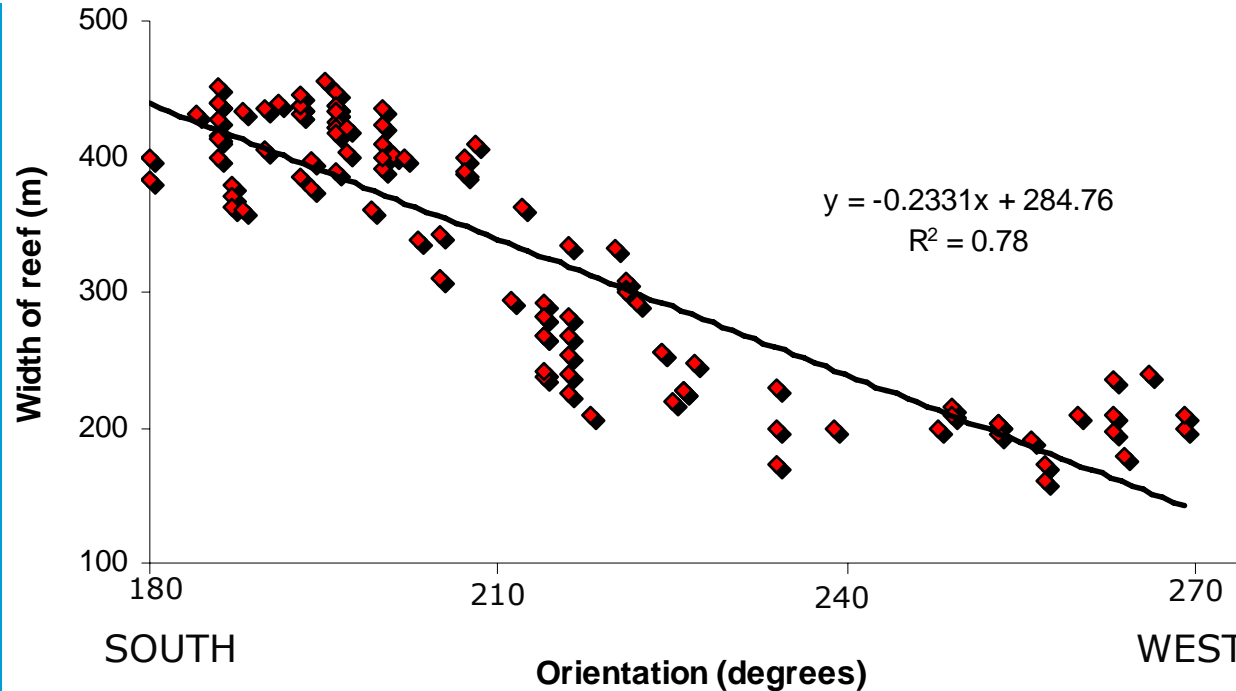
Platforms have an asymmetric facies distribution

- Side 1: fully aggraded reef (with or without apron)
- Side 2: land/ partially aggraded reef/platform
- Platform interior with or without isolated reefs



Asymmetry results in a variability of facies characteristics (e.g. reef belt width) within the platform

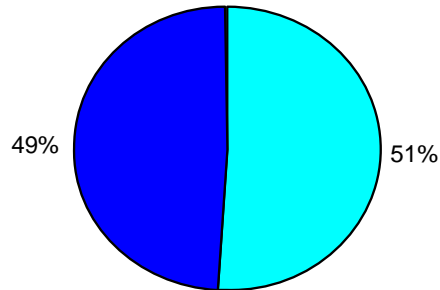
Reef Width and Physiographic Setting



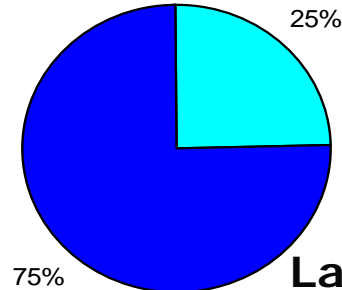
Variability of reef width to be expected over platform

Facies Abundance and Platform Size

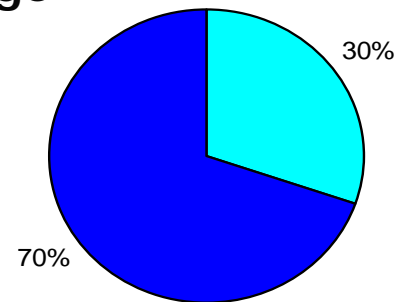
Small



Intermediate



Large



**'Small' platforms
contain proportionally
more potential reservoir
(incl. reef, apron,
shoals, shallow lagoon)**

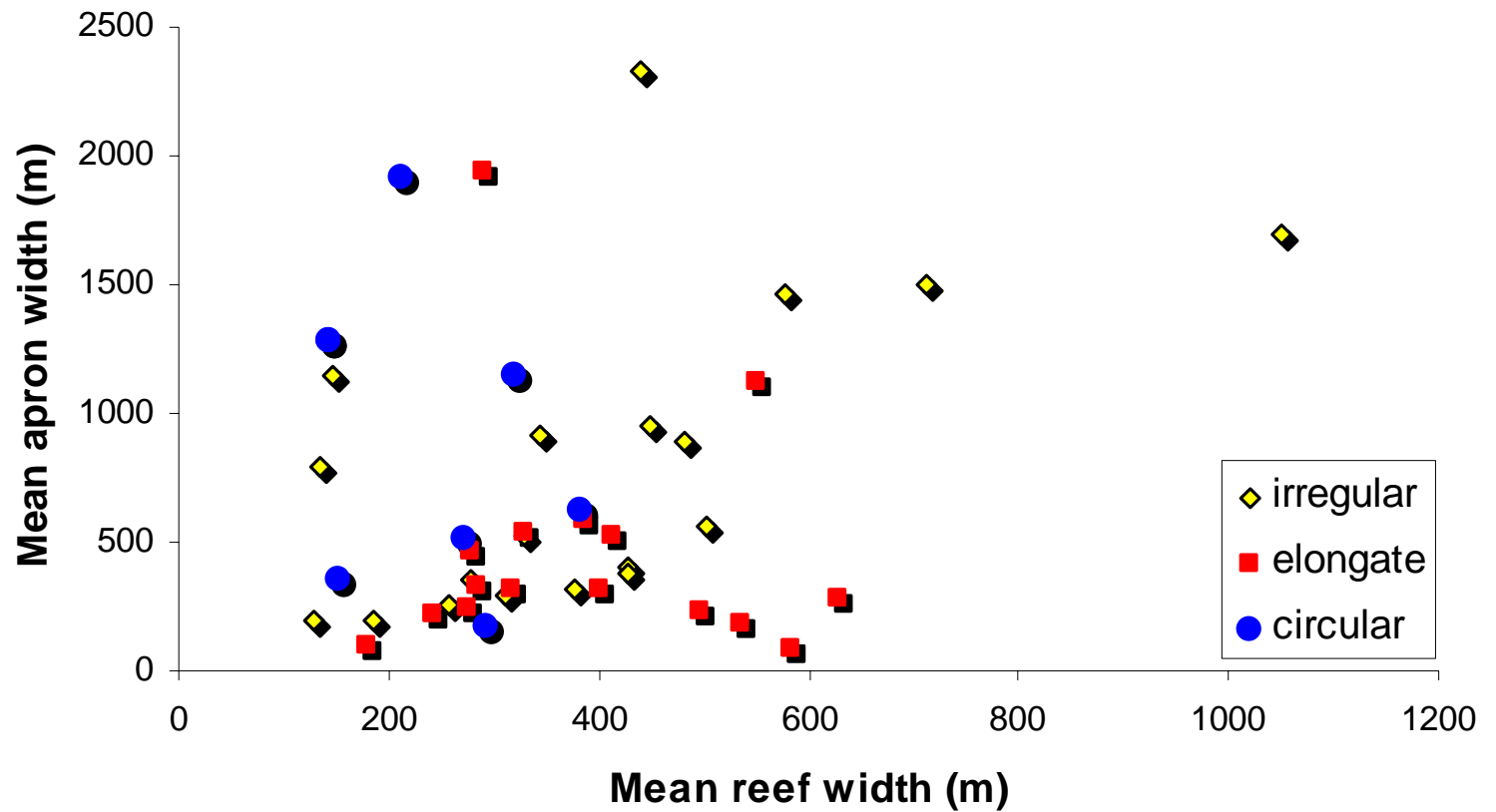
■ shallow platform facies
■ deep platform facies

Outline

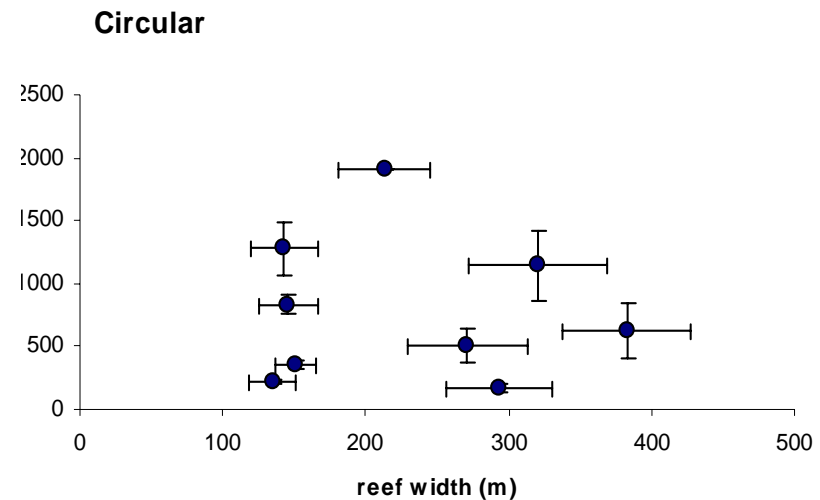
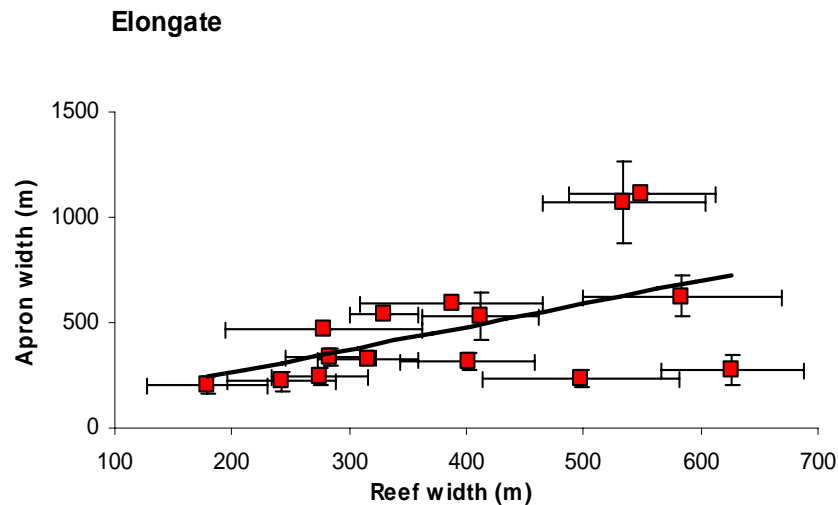
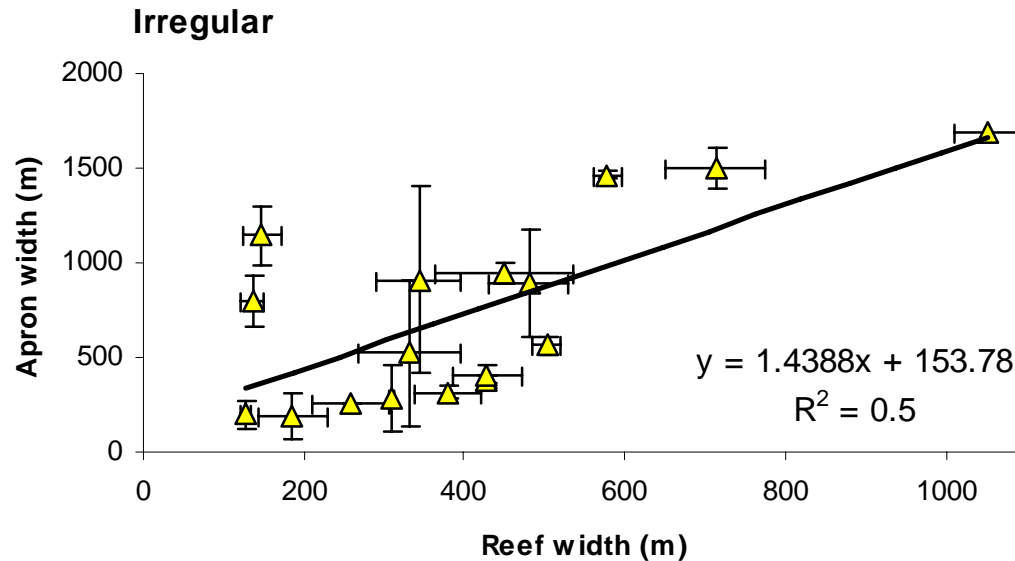
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Reef Belt Metrics

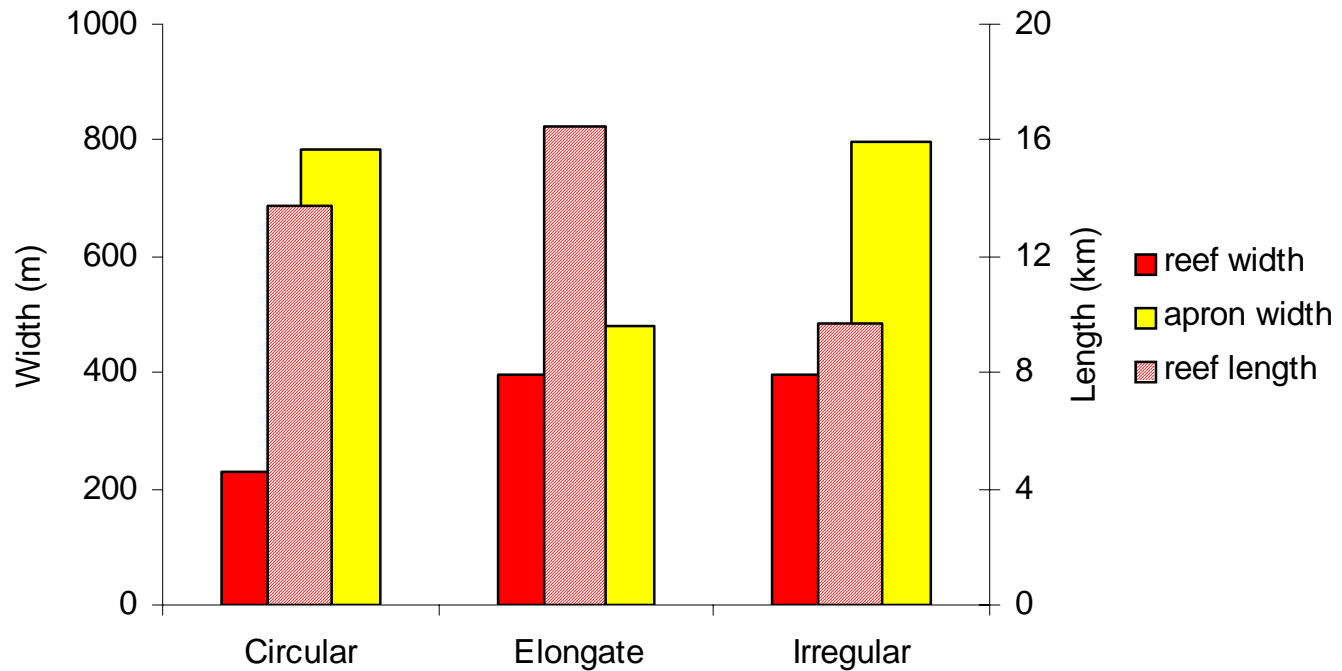
Apron/Reef width



Data Separated – by Shape

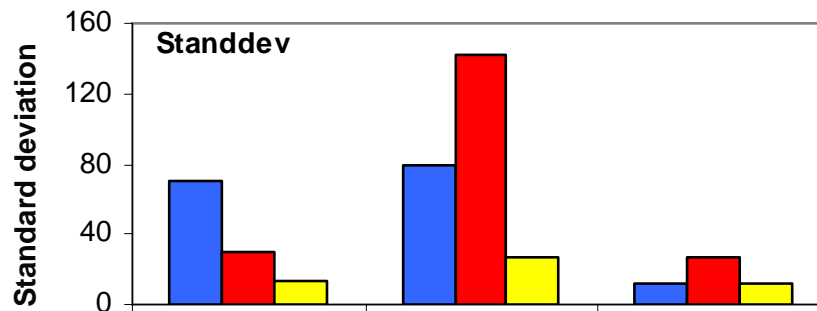
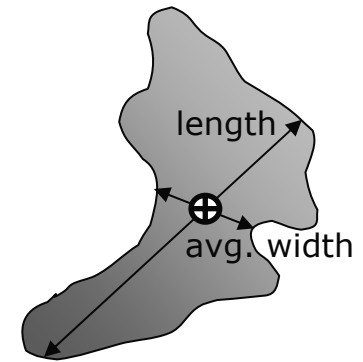


Reef Belt Metrics



- Circular platforms have the narrowest reef (≈ 230 vs 400 m)
- Elongate platforms have the narrowest apron (≈ 480 vs 800 m)
- Irregular platforms have the least continuous reef (≈ 10 km vs 14-16 km)

Aspect Ratio

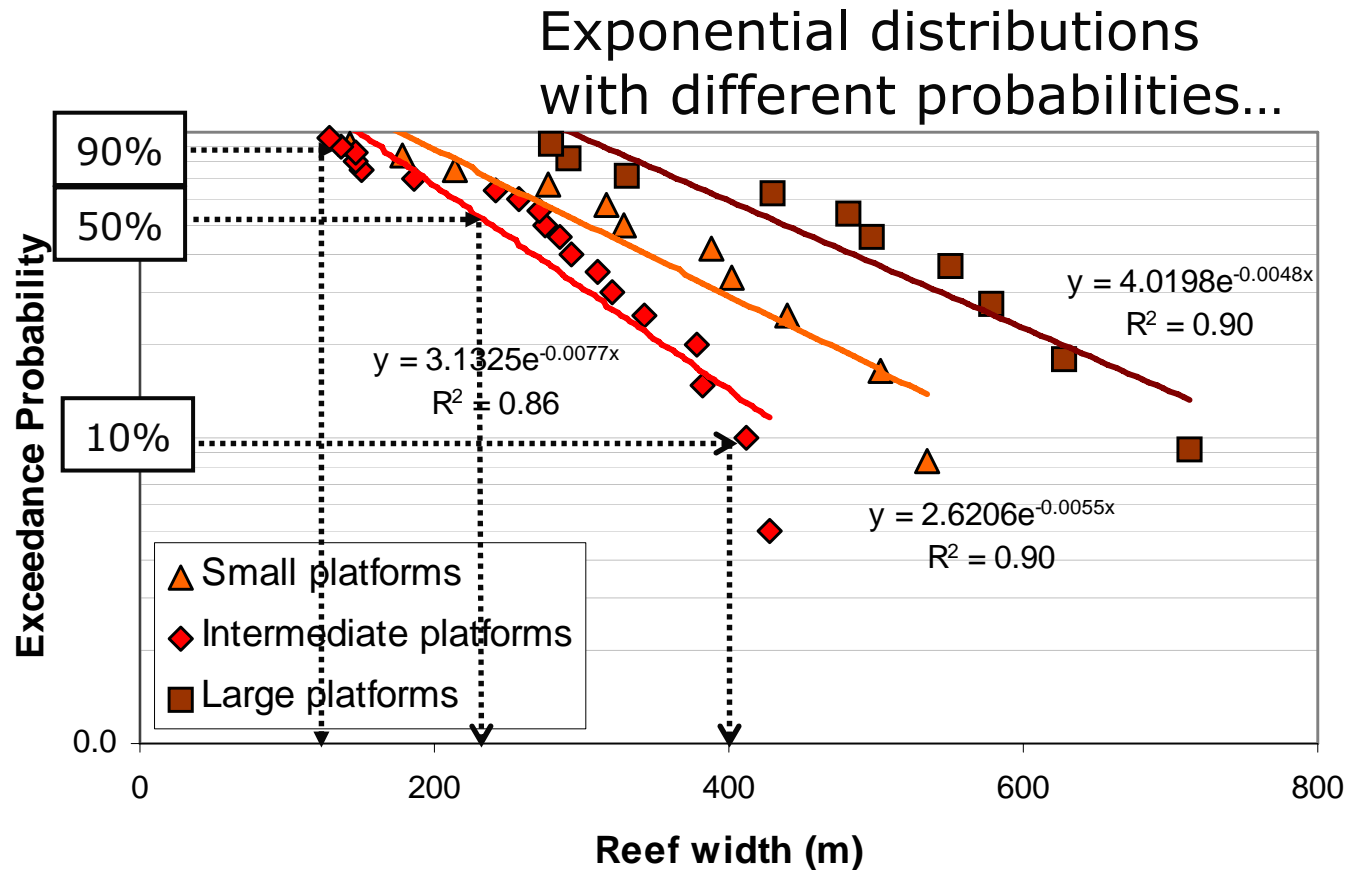


Irregular platforms have a significantly *lower aspect ratio* for reef facies **and** lower variability



Reefs are consistently shorter/wider

Platform Size and Reef Width



On any size platform...

10% probability: reef width > 400 m
50% probability: reef width > 240 m
90% probability: reef width > 120 m

Conclusions for the development geologist

- Number of facies is independent of platform size
- Platforms have asymmetric facies distribution
- 'Small' platforms contain proportionally more potential reservoir than 'large' platforms

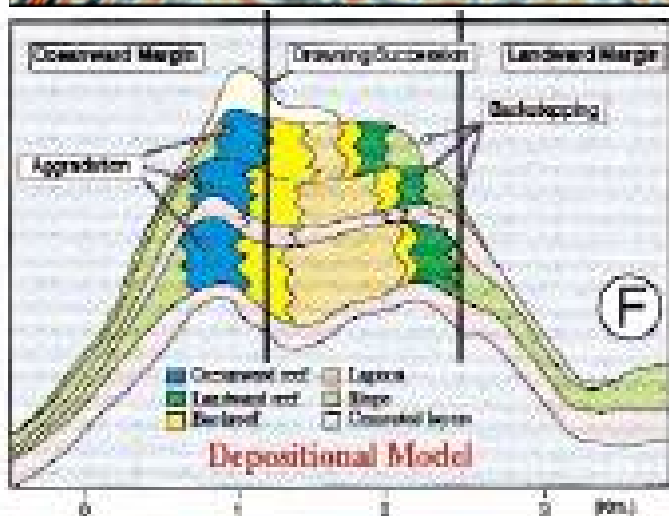
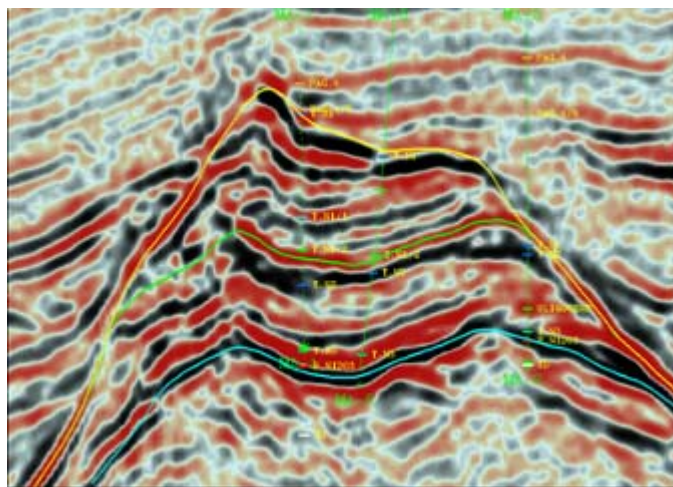
Conclusions for the modeler

- Trends represent predictive tools:
 - Platform size and relative abundance reef
 - Reef width and apron width: by shape of platform
 - Reef width and orientation

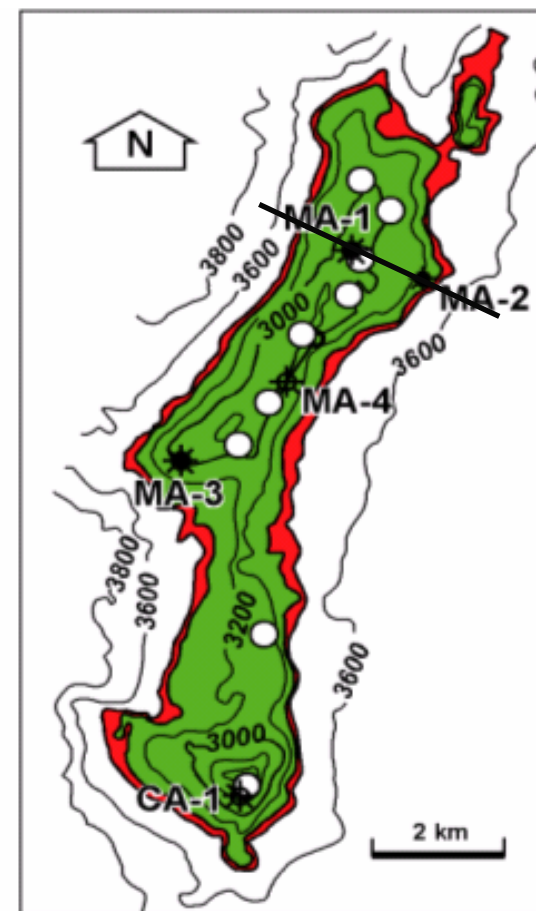
- “Hard” numbers for reef belt facies
 - Width and variability
 - Length and variability
 - Aspect ratio

Ancient analog example

Malampaya, Philippines

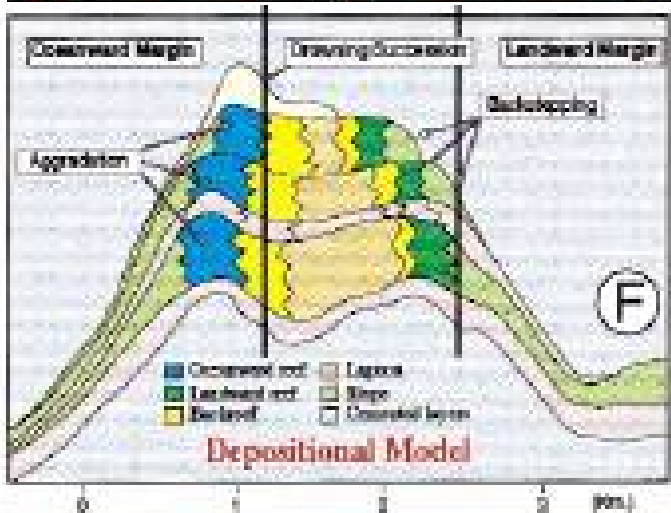
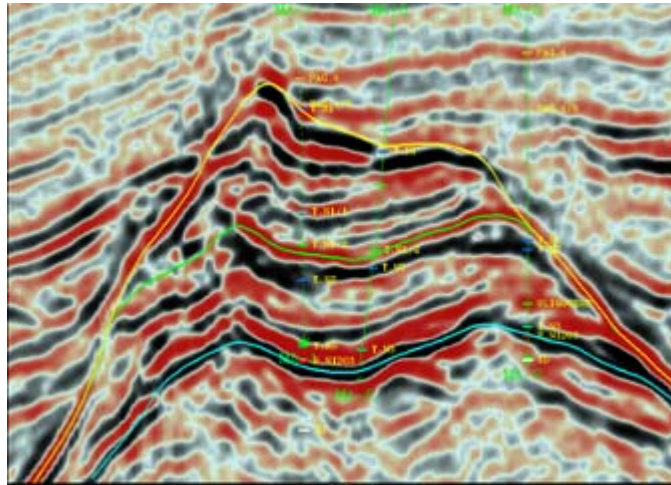


Grötsch and Mercadier, 1999



Ancient analog example

Malampaya, Philippines



Grötsch and Mercadier, 1999

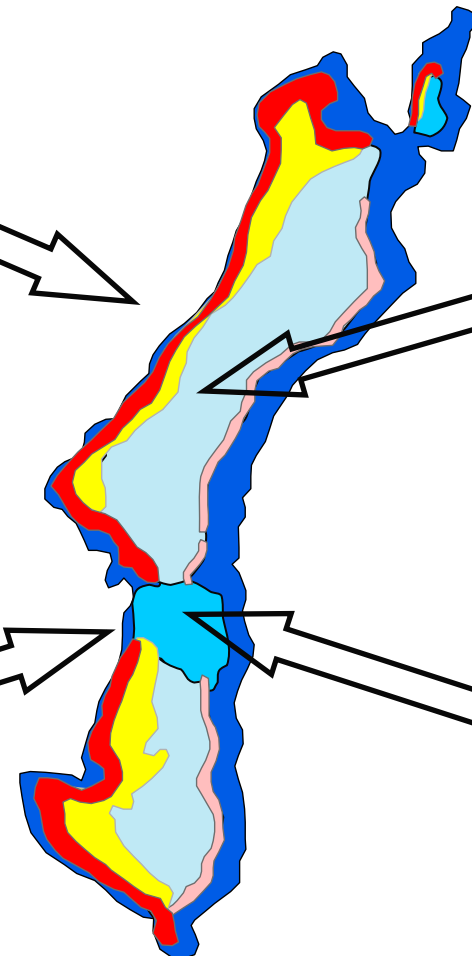
Conceptual facies depocenter map

FACIES	reef
width	6
Stdev width	1
length	7
Stdev length	3
Aspect ratio	21
abundance	19
orientation	41

FACIES	reef
width	6
Stdev width	1
length	7
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Thanks to..

Dave Stodola

Marjorie Levy

Frank Harris



Comparative Sedimentology Laboratory

