PS Input for Carbonate Reservoir Models: Trend Metrics of Modern Platforms and Reef Systems*

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Abstract

An accurate facies model is essential for reservoir development and 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) and variation of facies dimensions is 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 from the Caribbean and Indo-Pacific regions are used as analogs to offer insights into potential facies heterogeneity of carbonate reservoirs.

The workflow for identifying and quantifying attributes of facies tracts included integrating literature and satellite 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 ER Mapper. Reservoir facies included fully aggraded reef, partially aggraded reef, reef apron, shoals and shallow platform interior. 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 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 versus number/abundance of facies or size of platform versus shape complexity.) These kinds of "rules" provide both general concepts and raw data that can be used as input for enhanced carbonate models.

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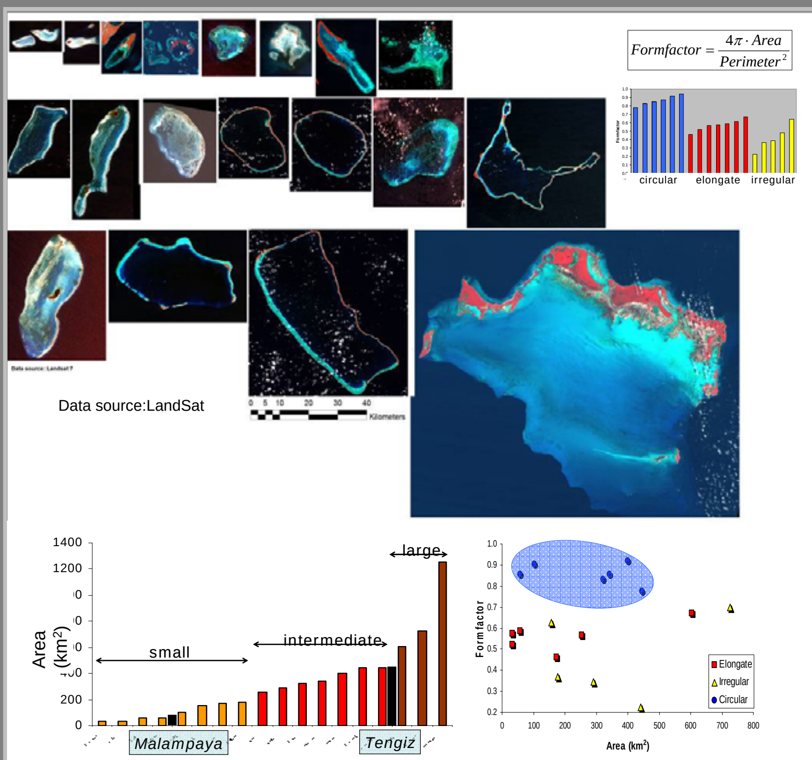
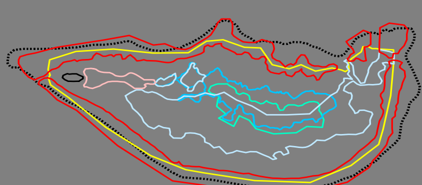
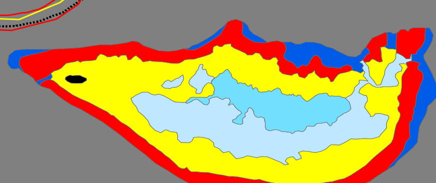
Rationale

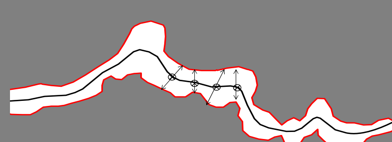
- An accurate facies model is essential for realistic reservoir modeling, as depositional facies can be a main parameter controlling heterogeneity in porosity and permeability
- Prediction of the quantitative attributes (size, shape, orientation, distribution, etc.) and variation of facies dimensions is fundamental for enhanced reservoir simulations for carbonate systems

Data – Grouped by size and shape





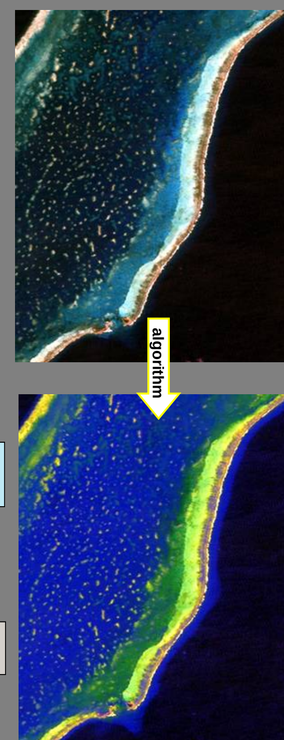




Workflow

ER Mapper:

1. Import raster layers
2. Specific algorithm 1 (filter, transform, combine bands)
3. Processed image highlighting one feature
4. Digitize feature 1
5. Specific algorithm 2
6. Processed image highlighting different feature
7. Digitize feature 2
8. Export polygons to ArcMap



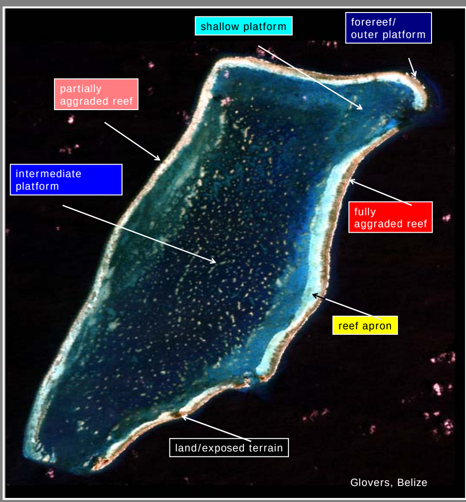
ArcGIS:

1. Import polygons as shapefiles
2. Define coordinate system (WGS84, UTM zone)
3. "Clean" polygons
4. Measure area – perimeter
5. *Visual Basic coding*
   1. transform shapefile to raster
   2. calculate centerline for each polygon
   3. calculate width and azimuth every 100 m along centerline
   4. output table with width, length, azimuth, sinuosity
6. Export attribute tables to Excel

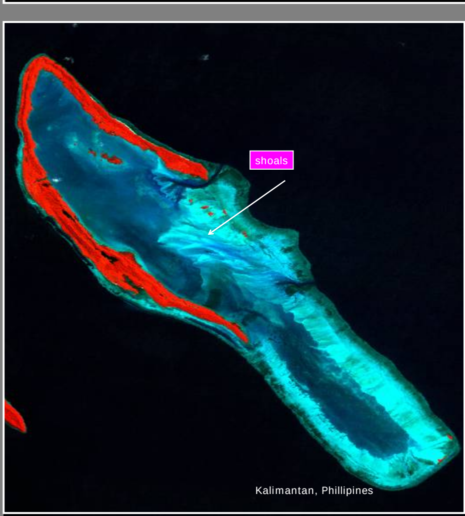
Objectives

- 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
- Provide an organized, web-based database with quantitative data of modern analogs of carbonate fields

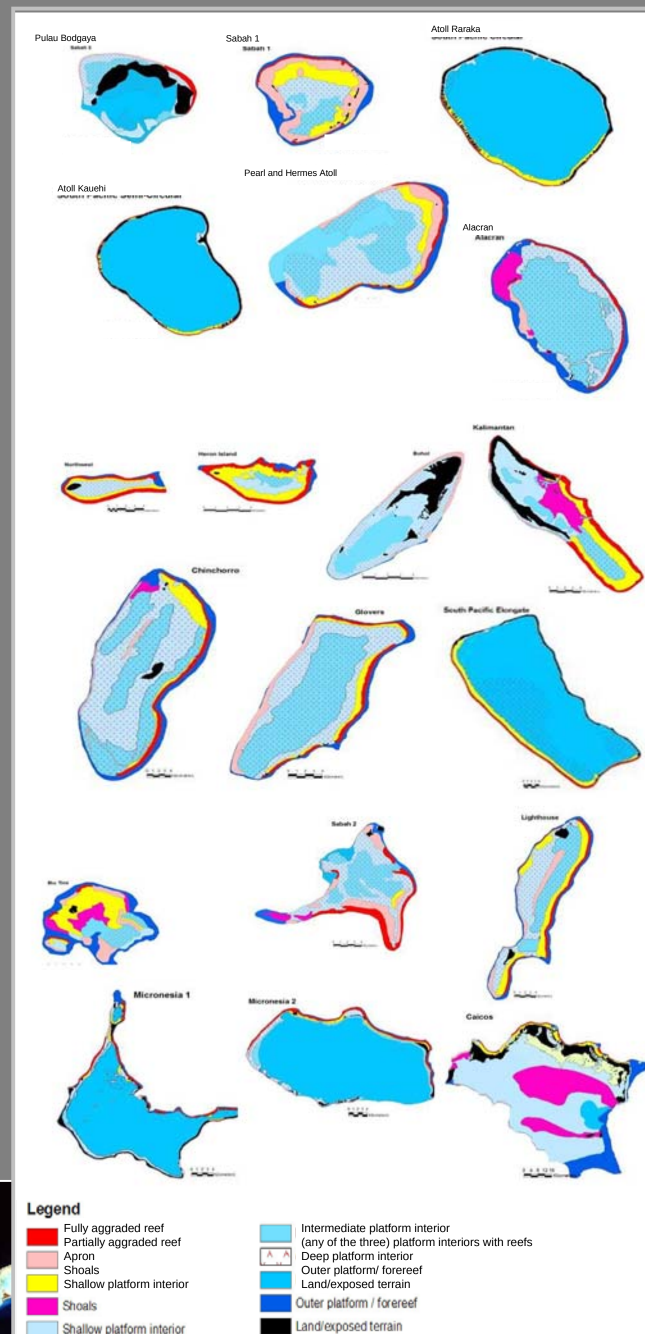
Facies



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



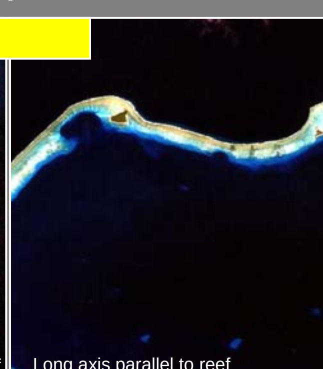
Facies maps



Objective Reproducible Criteria

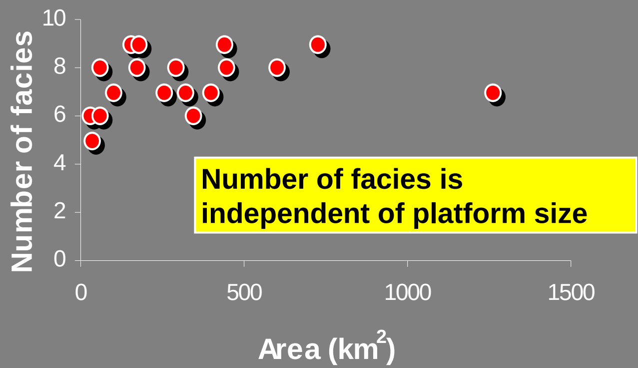
Color, context, texture and shape

Reef apron examples

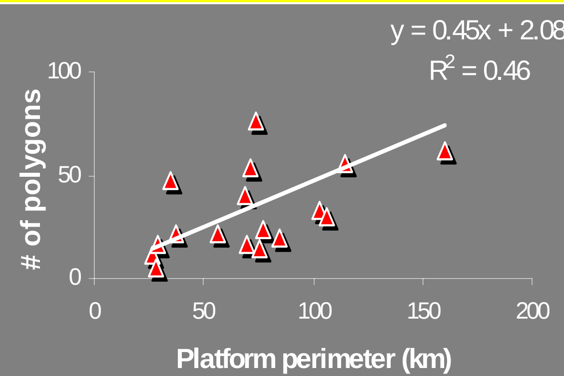


Landscape Scale ‘Rules’

Composition

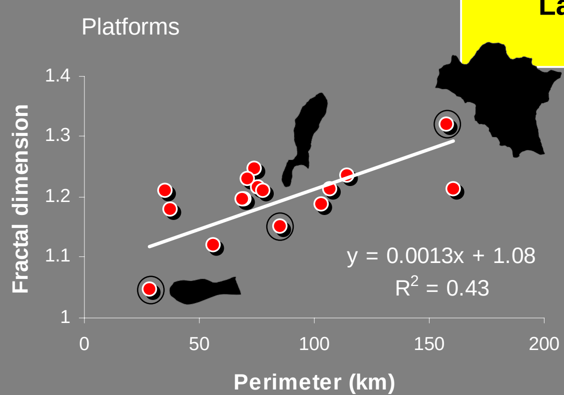


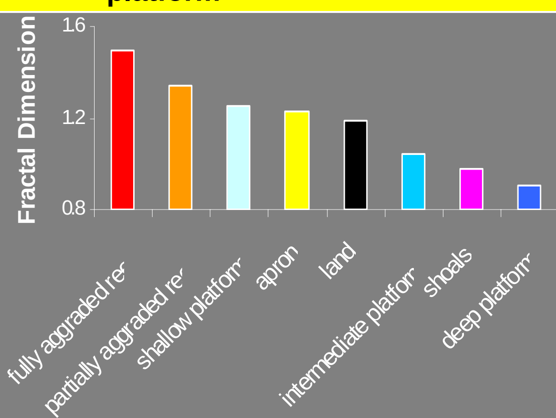
Larger platform perimeter → more facies polygons



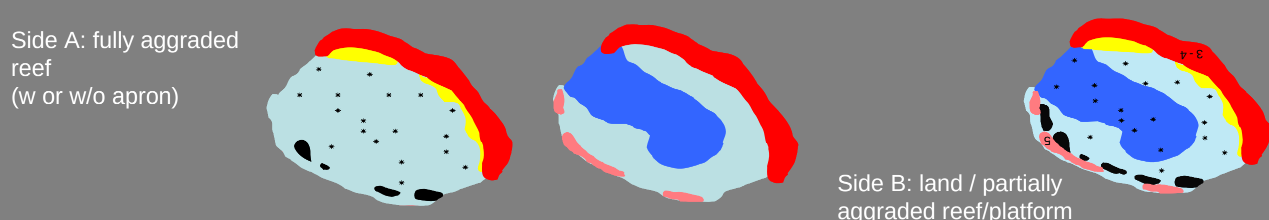
Shape complexity

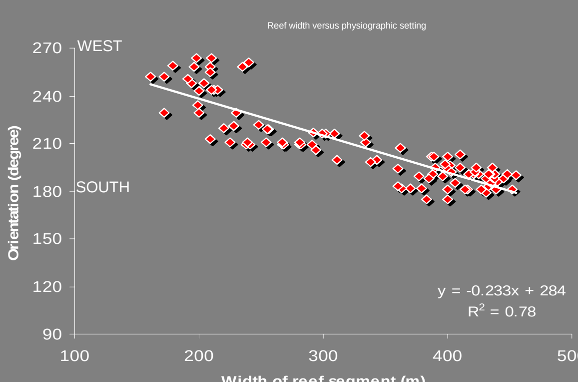
Larger platform perimeter → more complex facies shapes within platform





Platform configuration



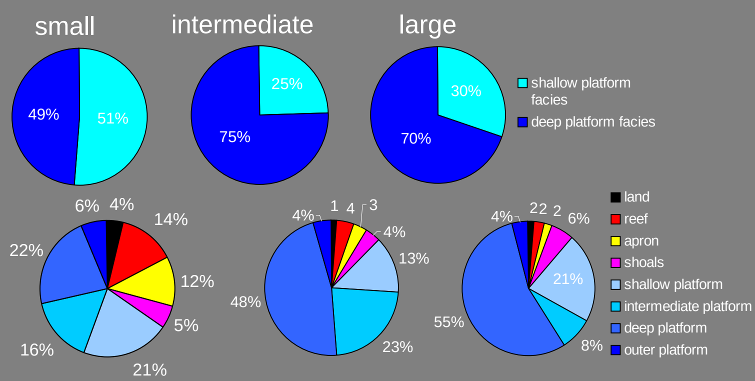


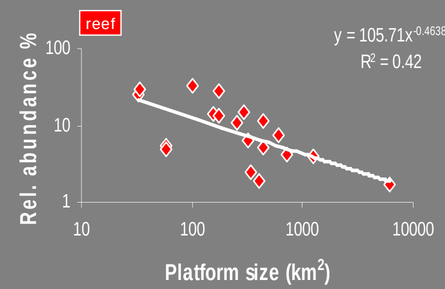
Asymmetric facies configuration leads to variability of facies characteristics within the platform.

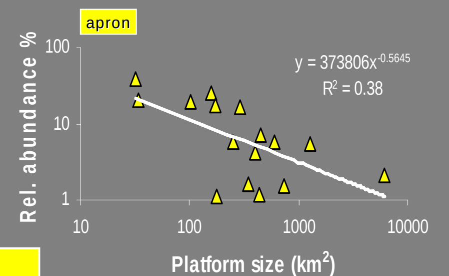
Windward side of platform is expected to show higher standard deviation of reef width than leeward side.

Facies Metrics

Facies proportions





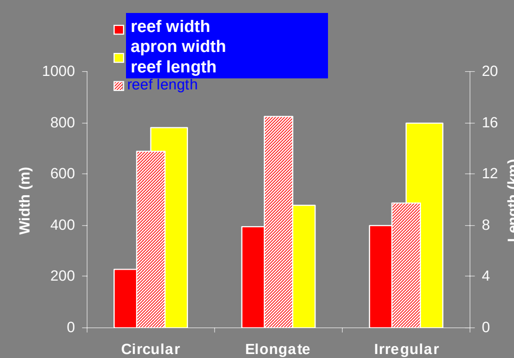


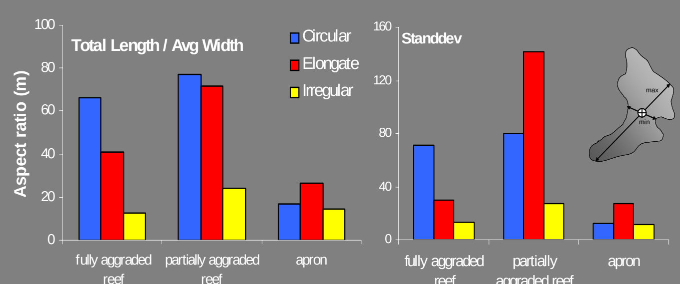
'Large' platforms contain proportionally less potential reservoir (reef, apron, shoals, shallow lagoon) than 'small' platforms

Power law relationships

Reef belt metrics

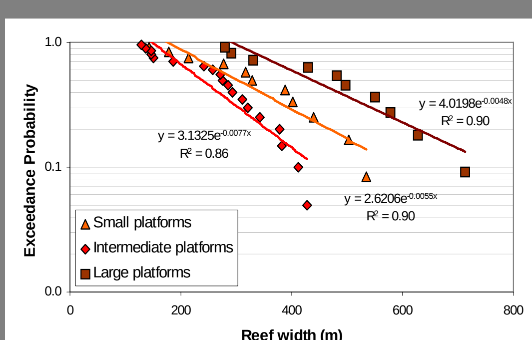
- **Circular platforms - narrowest reef**
- **Elongate platforms - narrowest apron**
- **Irregular platforms - least continuous reef**

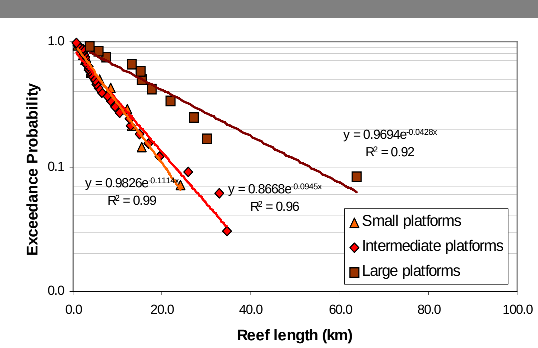


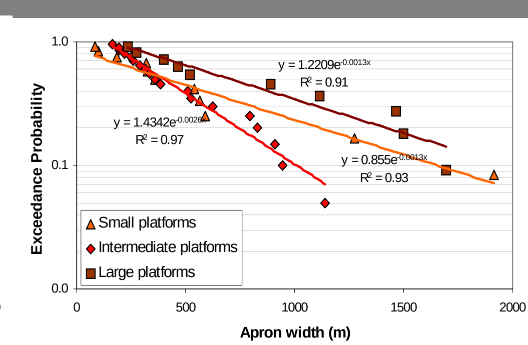


Irregular platforms have a significantly lower aspect ratio for its reef facies.
Reefs are *consistently* shorter and wider

Exceedance probability







On any size platform...

10% probability: reef width > 400 m	**reef length > 20 km**	**apron width > 950 m**
50% probability: reef width > 240 m	**reef length > 5 km**	**apron width > 400 m**
90% probability: reef width > 120 m	**reef length > 1 km**	**apron width > 100 m**

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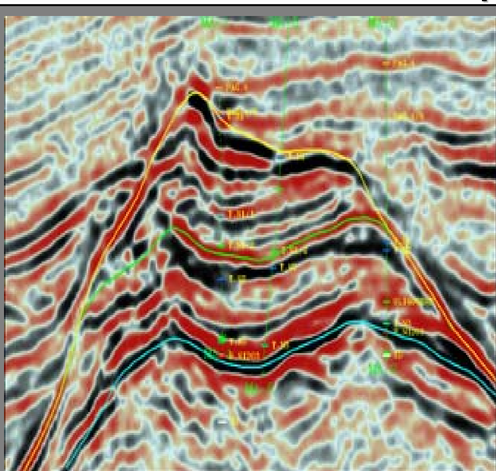
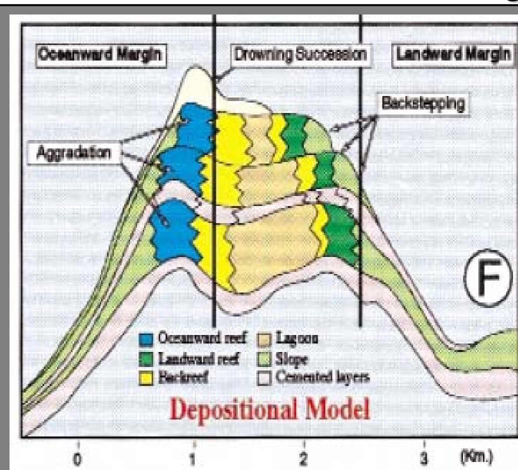
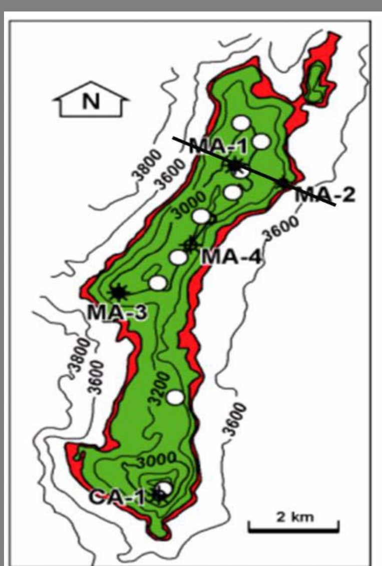
Implications for Reservoir Modeling

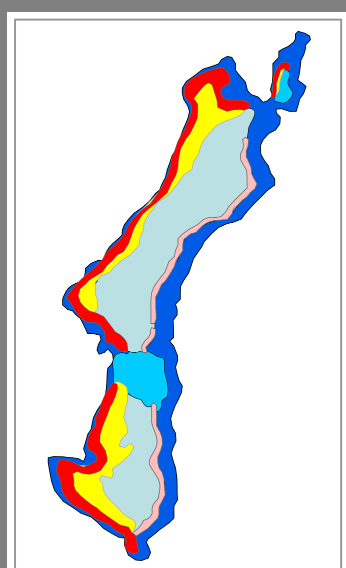




Grötsch and Mercadier, 1999

Malampaya is an isolated carbonate platform with a reef rim and an asymmetric facies distribution over the platform.

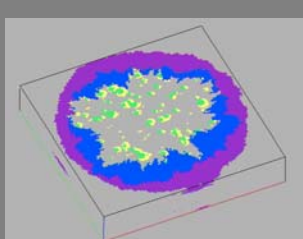


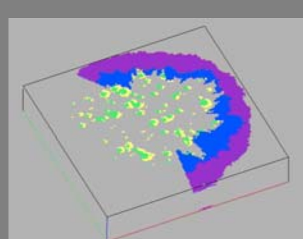


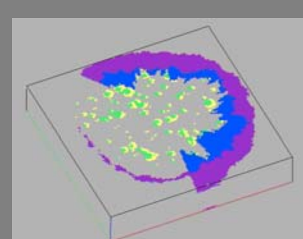
Landscape scale 'rules' explored on modern platform analogs provide information on conceptual facies depocenters

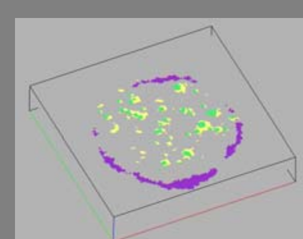
FACIES	Rock type	% Rel. Abundance	Avg width (m)	Range (m)	Avglength (km)	Aspect ratio(m)	Sinuosity
Fully aggraded reef	Boundstone Rudstone	6	387	150-625	16.5	41	0.21
Partially aggraded reef	Boundstone Rudstone Grainstone	1	196	115-300	11.3	71	0.09
Apron	Rudstone Grainstone	7	565	130-965	14.8	27	0.2
Shoals	Grainstone	3	2445	655-3395	6.8	3	
Shallow platform	Packstone	21					
Intermediate platform	Packstone Wackestone	19					
Deep/outer platform	-	41					

Facies metrics obtained from (elongate) platform analogs provide input parameters for training images that are used in Multiple Point Statistics (MPS) reservoir models.









Fully aggraded reef with apron

Partially aggraded reef