

**PS Carbonate Reservoir Modeling Using  
Multiple-Point Statistics (MPS) / Facies Distribution Modeling (FDM)\***

By  
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**Abstract**

We have explored the use of MPS/FDM modeling in a carbonate reservoir. We have modeled the platform top of an isolated platform example and tested various scenarios for the distribution of grainstone facies.

The training image is a 3D conceptual model of the reservoir, containing information about facies dimensions and relationships among facies. Five facies were considered: Bar crest = best reservoir quality due to sorting in “highest energy” setting; Bar flank = good reservoir quality between bar crests, includes flanks of bars and intervening tidal channels; Island = localized areas where permeability is enhanced by dissolution during meteoric diagenesis; Deeper platform = poorer reservoir quality in platform areas away from bars and channels; and Background = “tight” intervals due to muddier facies or to porosity-plugging cementation.

The facies probability cube allows controlling the spatial distribution of the facies in the MPS model. First, facies depocenter maps were generated for deeper platform, bar flank, bar crest and island. Then, the stratigraphy of the reservoir was modeled by digitizing a vertical proportion curve reflecting the variations of facies proportions with depth. Three alternative vertical proportion curves were created, representing respectively a gradual trend, cyclicity at the scale of composite sequences, and high cyclicity at the scale of individual sequences. Corresponding alternative facies probability cubes were generated for these three cases.

Several scenarios were run: the gradual, cyclic and highly cyclic cases; both narrow and wide bar crests and bar flanks; and with constant and variable azimuth. The wide bar crest/bar flank and very cyclic simulation produce results that qualitatively appear most reasonable in both cross section and map views.

# Carbonate Reservoir Modeling Using Multiple-Point Statistics (MPS) / Facies Distribution Modeling (FDM)

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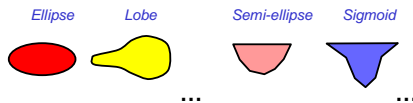
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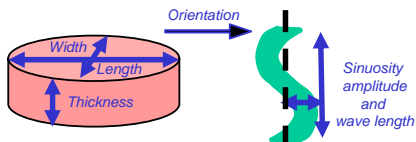
## Training Image Generation

### 1. Describe geometry of each facies:

- Define map view and cross-section shapes



- Define dimensions, orientation, sinuosity

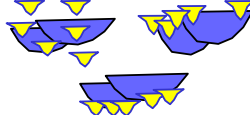


### 2. Specify relationships among facies:

- Define facies erosion rules



- Define vertical and/or horizontal constraints

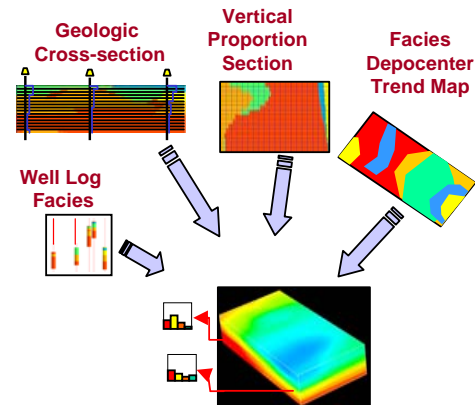


## MPS (Multiple-Point Statistics)

MPS is an innovative depositional facies modeling technique, developed by Chevron in collaboration with Stanford University, that uses 3D conceptual geological models as training images to integrate geological information into reservoir models. Replacing the traditional variogram with a training image allows MPS to capture complex spatial relationships between multiple facies, and to model non-linear shapes such as sinuous channels that conventional variogram-based modeling techniques typically fail to reproduce. In addition, because MPS is not an object-based, but still a pixel-based algorithm, MPS models can be constrained by very large numbers of wells and 3D facies probability cubes derived from seismic data or from reservoir facies deposition interpretation (using FDM).

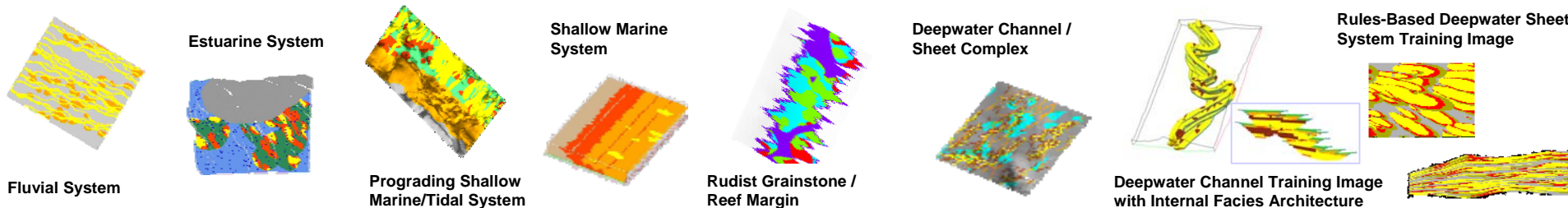
For the last three years, the MPS/FDM workflow has been preferred to variogram-based and object-based techniques to model important Chevron assets in both shallow-water clastic reservoirs (Indonesia and Angola), and deepwater reservoirs (Gulf of Mexico, North Sea, Angola, and Nigeria). In those projects, the MPS/FDM workflow enabled the generation of geologically realistic facies models, which significantly improved reservoir OOIP and oil recovery uncertainty assessment.

## FDM (Facies Distribution Modeling)



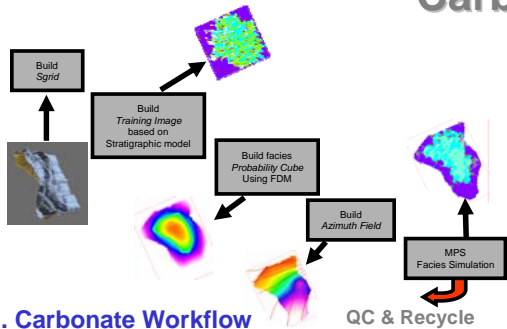
3D Facies Probability Cube

## Training Image Library:



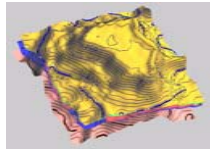
# Carbonate Reservoir Modeling Example Using MPS / FDM

## 1. Carbonate Workflow

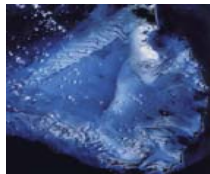


## 2. Study Rationale

Focus on isolated carbonate platform example

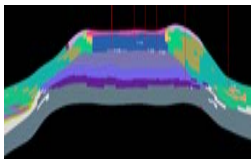


Use modern analogs for conceptual facies models



Test application of current MPS/FDM tools to carbonate modeling

Develop "new" tools specific for carbonates



Model only platform and test varied scenarios for distribution of grainstone facies

## 4. Build Training Images

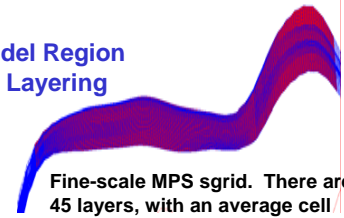
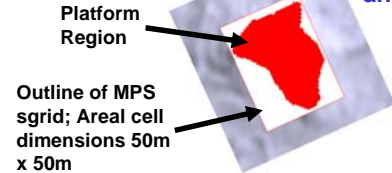
### 4a. Rationale of Training Images

Platform top has widespread grainstones. We suspect that some type of bar and channel (flank) morphology is likely.

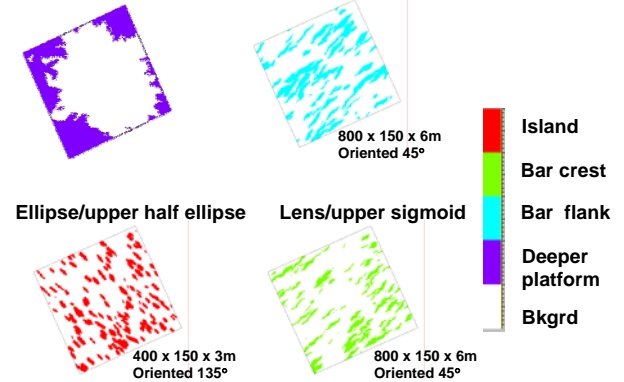
- Island = localized areas where permeability is enhanced by dissolution during meteoric diagenesis
- Bar crest = best reservoir quality due to sorting in "highest energy" setting
- Bar flank = good reservoir quality between bar crests, includes flanks of bars and intervening tidal channels
- Deeper platform = poorer reservoir quality in platform areas away from bars and channels
- Background = "tight" intervals due to mudrier facies or to porosity-plugging cementation

Landsat image  
Berry Islands, Great Bahama Bank

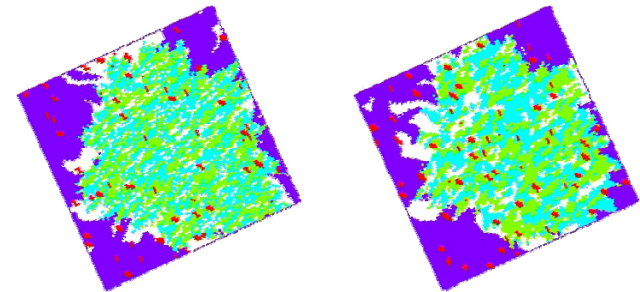
## 3. Model Region and Layering



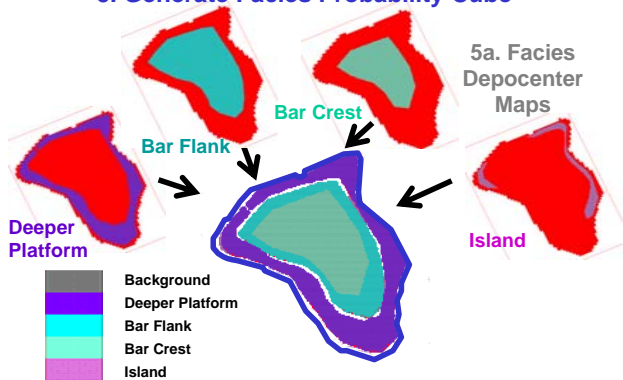
## 4b. Single Facies Training Images



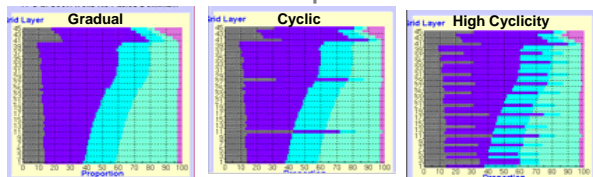
## 4c. Combined Facies Training Images



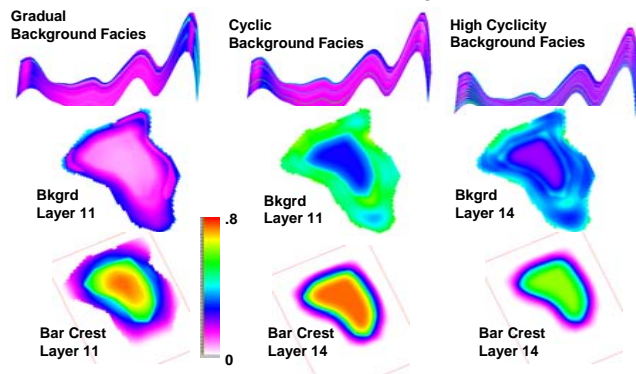
## 5. Generate Facies Probability Cube



### 5b. Facies Proportion Curves



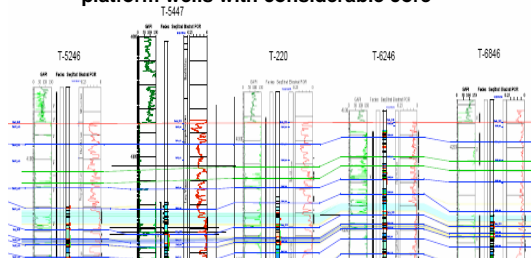
### 5c. Alternative Facies Probability Cubes



## 6. Add Well Data Conditioning and other Modeling Constraints

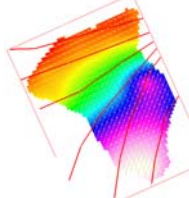
### 6a. Control from Cored Wells

Facies control provided from a subset of platform wells with considerable core



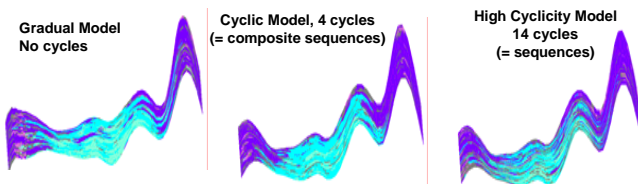
- Lithofacies described in each core were regrouped into the MPS/FDM facies
- MPS/FDM facies indices were assigned to each cored well and used for conditioning of the model

### 6b. Add Variable Azimuth



## 7. Run MPS Simulation

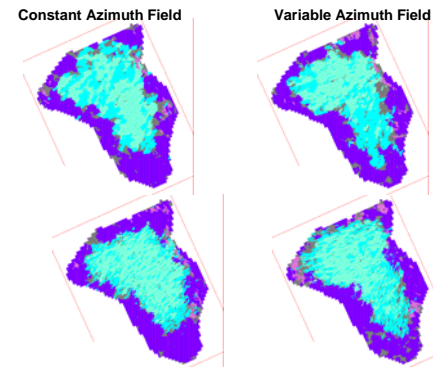
### 7a. MPS Simulation in Cross Section



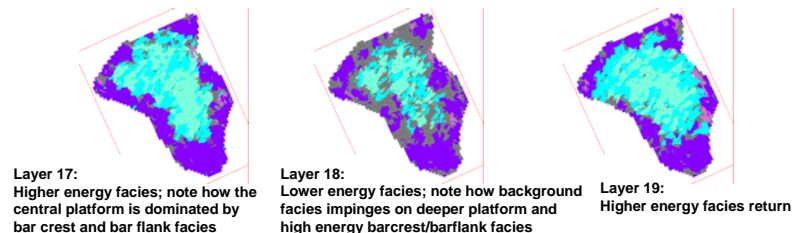
## 7b. MPS Simulation in Map View

MPS simulation with wide bar crest and wide bar flank facies

MPS simulation with narrow bar crest and narrow bar flank facies



### 7c. Wide Barcrest/Barflank, High Cyclicality Model



## 8. Model Summary

Matches facies regions of platform top which were defined during reservoir characterization

Matches stratigraphic variation defined during sequence stratigraphy studies with facies proportion curves

Matches conceptual models for facies types from modern analogs with training images

Generally matches facies identified in cored wells

