Multiple-Point Statistics (MPS)/Facies Distribution Modeling (FDM) of Carbonates – an Isolated Platform Example*

By
Marjorie Levy[1], Paul M. (Mitch) Harris[1], and Sebastien Strebelle[1]

Search and Discovery Article #40292 (2008)
Posted July 30, 2008

*Adapted from oral presentation at the 2006 AAPG International Conference and Exhibition, Perth, Australia, November 5-8, 2006

[1]Chevron Energy Technology Company, San Ramon, CA (levm@chevron.com; MitchHarris@chevron.com; stsb@chevron.com)

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.
- 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,
- 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. Flow simulation of the various models highlights their significant differences.

Multiple-Point Statistics (MPS) / Facies Distribution Modeling (FDM) of Carbonates – an Isolated Platform Example

Marge Levy, Paul (Mitch) Harris, and Sebastien Strebelle

Chevron Energy Technology Company
San Ramon, CA U.S.A.

Carbonate MPS/FDM Modeling
Outline

Rationale for Modeling

Introduction to Case Study

MPS/FDM Modeling Steps and Results

Discussion

Carbonate MPS/FDM Modeling
Outline

Rationale for Modeling

Introduction to Case Study

MPS/FDM Modeling Steps and Results

Discussion

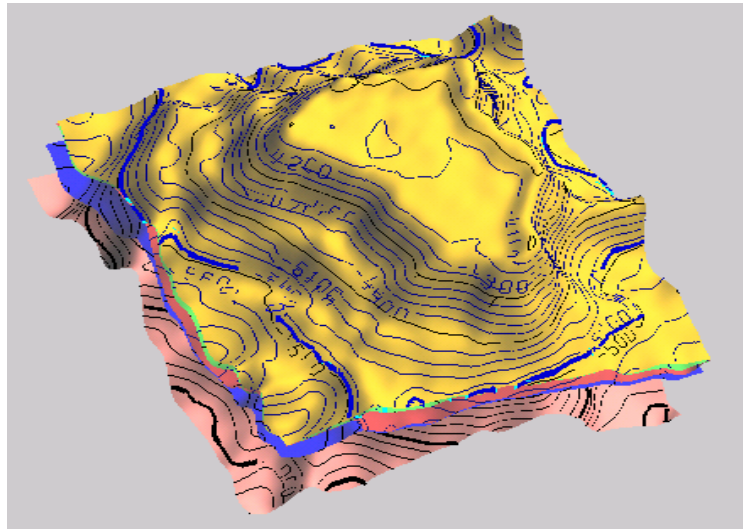
Carbonate MPS/FDM Modeling
Rationale of Project

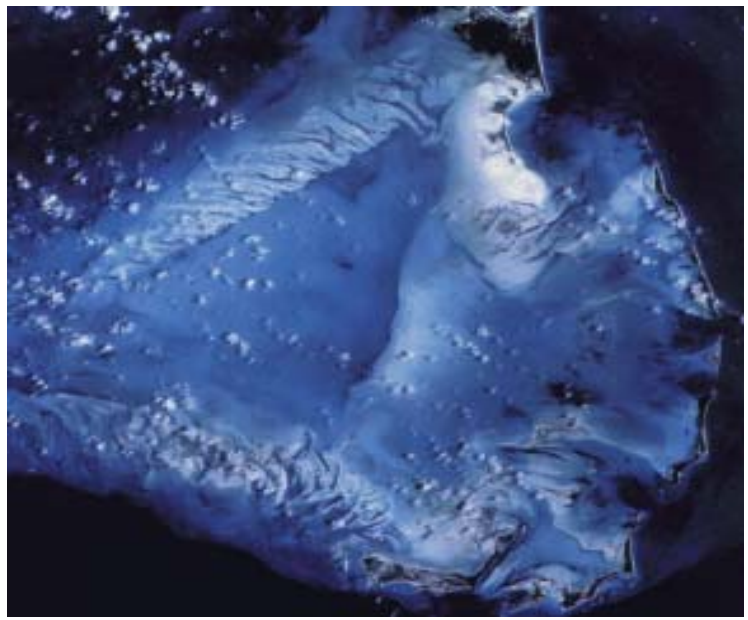
Focus on isolated carbonate platform example

Use modern analogs for conceptual facies models

Test application of current MPS/FDM tools to carbonate modeling

Develop “new” tools specific for carbonates





Carbonate MPS/FDM Modeling
Outline

Rationale for Modeling

Introduction to Case Study

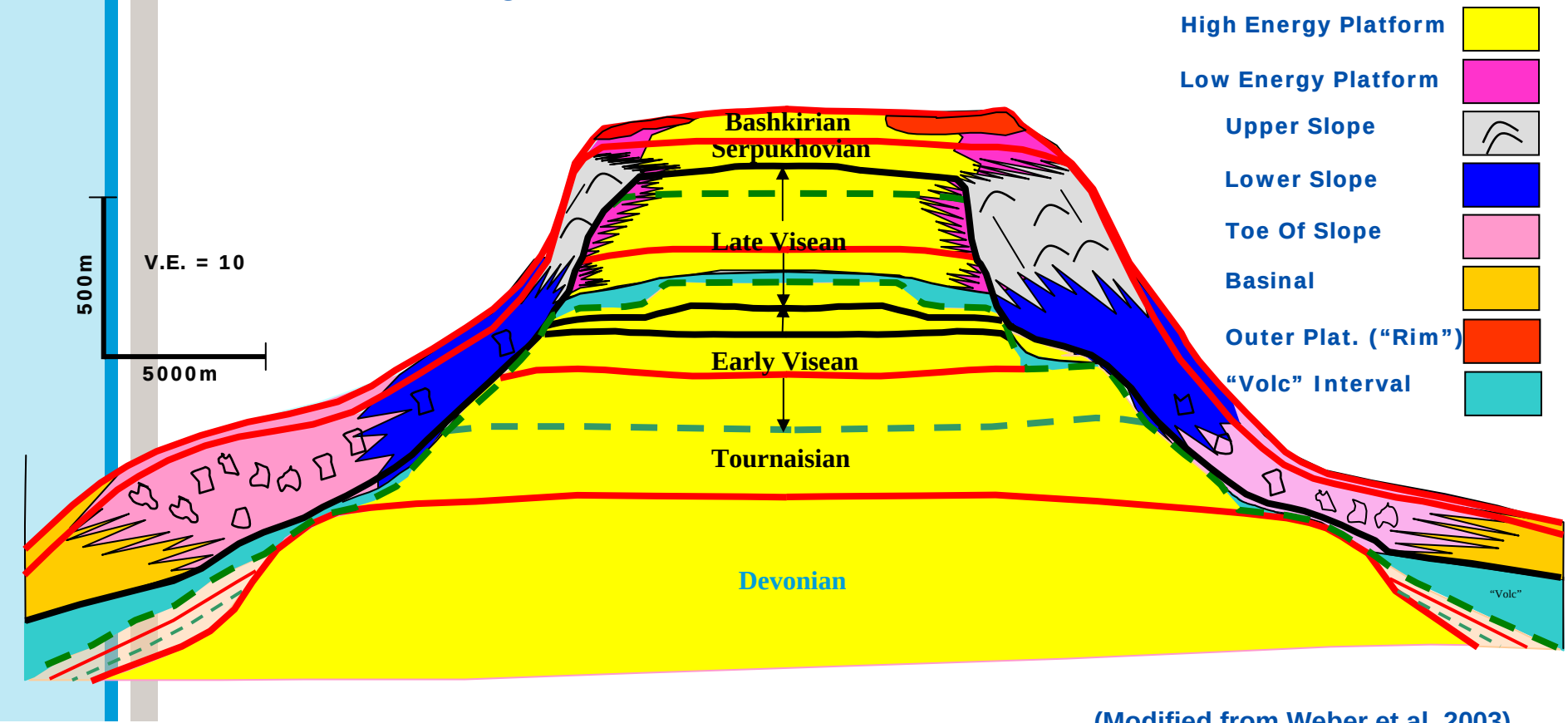
MPS/FDM Modeling Steps and Results

Discussion

Carbonate MPS/FDM Modeling
Choice of Case Study

Build models based on Tengiz reservoir (Weber et al, 2003); not building actual model of reservoir

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

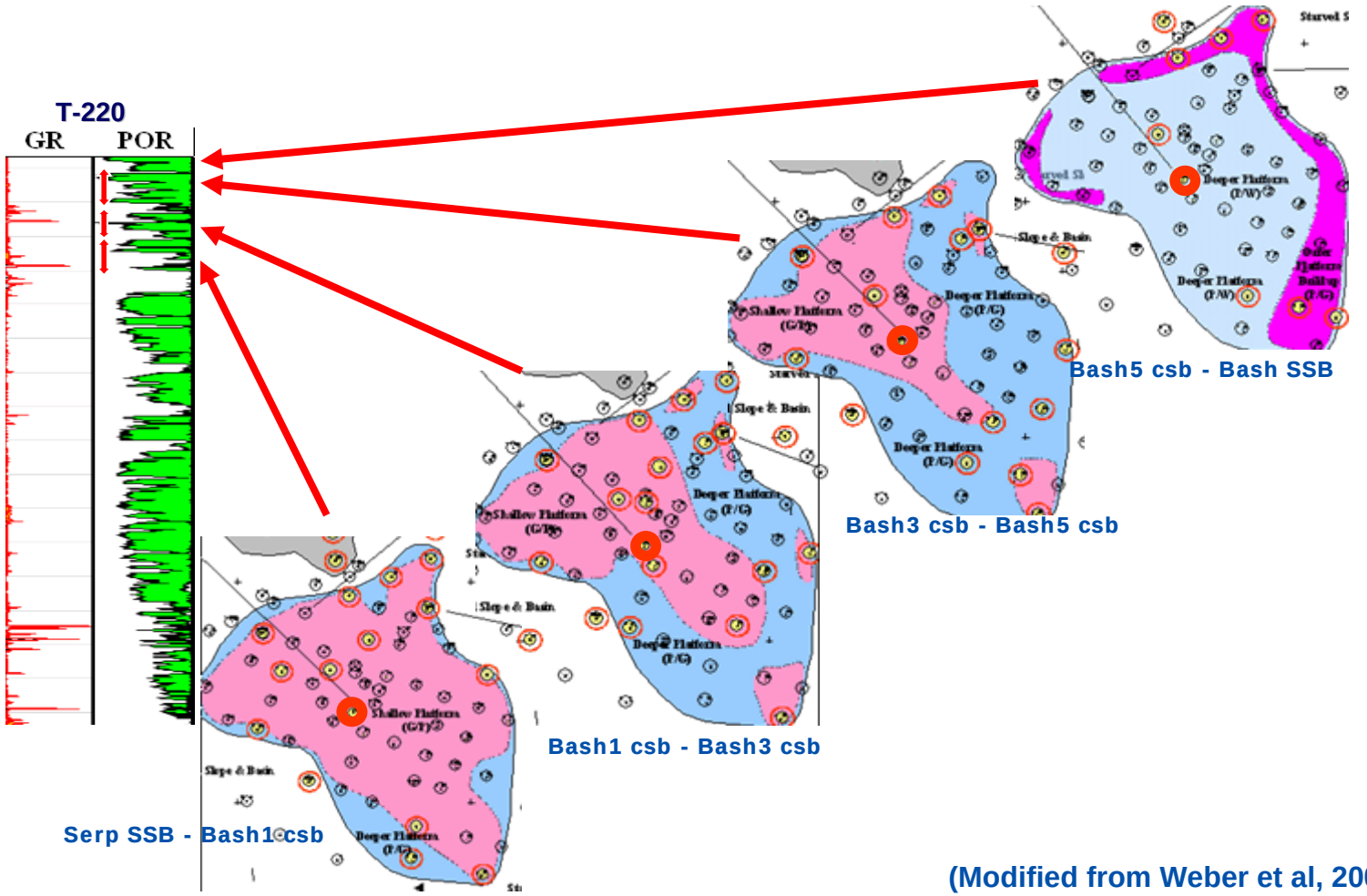


(Modified from Weber et al, 2003)

Carbonate MPS/FDM Modeling
Stratigraphy and Facies

Use principal layers as defined by sequence stratigraphy framework

Main lithofacies regions are shallow platform, deeper platform, and rim



(Modified from Weber et al, 2003)

Carbonate MPS/FDM Modeling
Outline

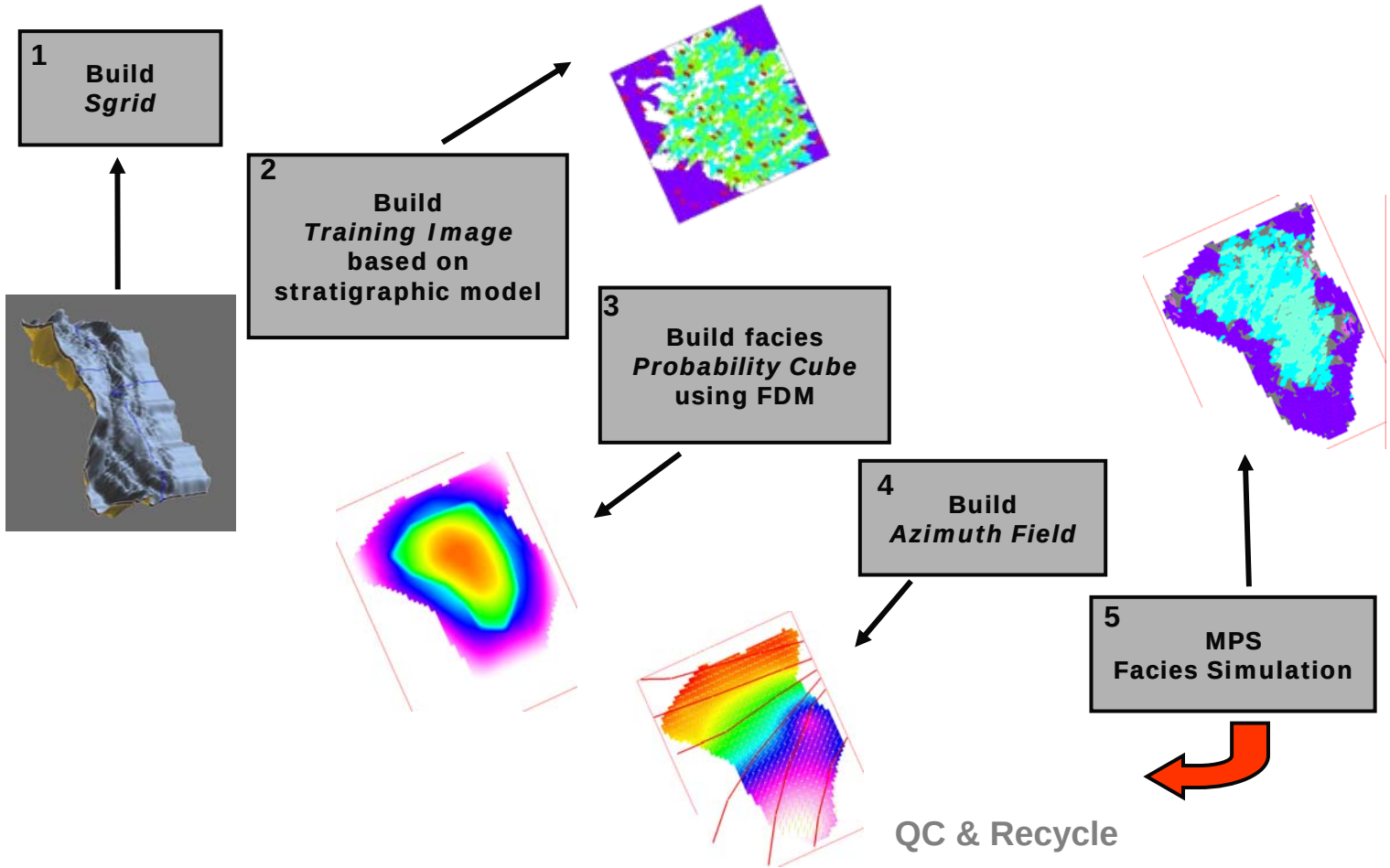
Rationale for Modeling

Introduction to Case Study

MPS/FDM Modeling Steps and Results

Discussion

Carbonate MPS/FDM Modeling Workflow



MPS/FDM Modeling Steps and Results

Define region and layering scheme

Generate Training Image
- Build single facies training images
- Combine individual training images

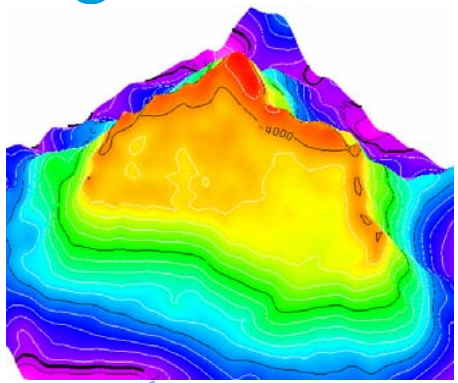
Generate facies probability cube
- Define facies depocenters
- Create vertical proportion curves

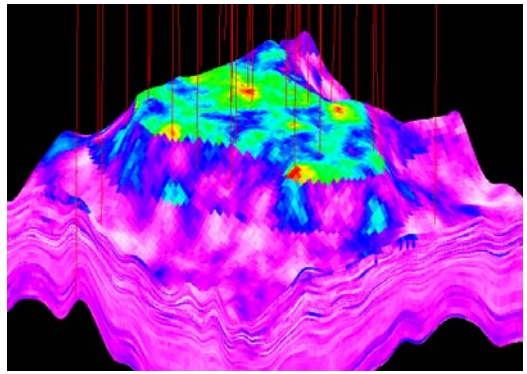
Add external constraints
- Variable azimuth field

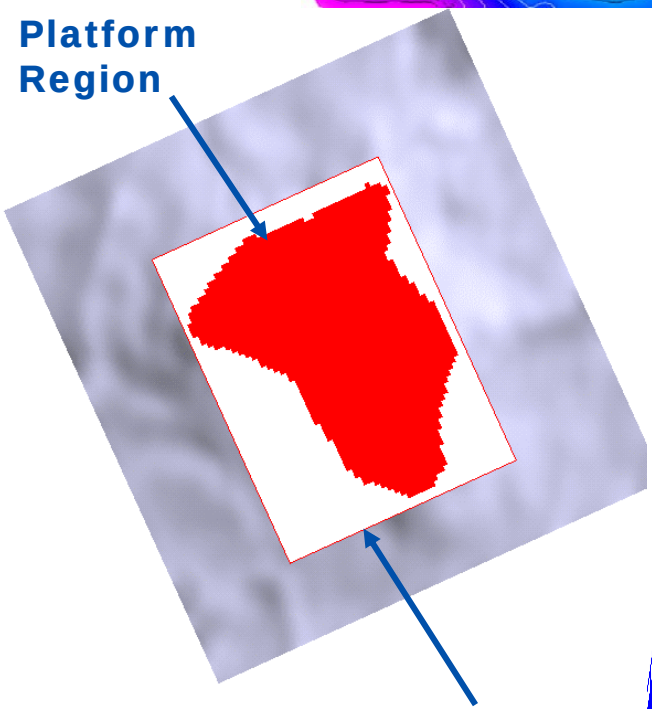
Calibrate cored wells for facies conditioning

Run MPS simulation

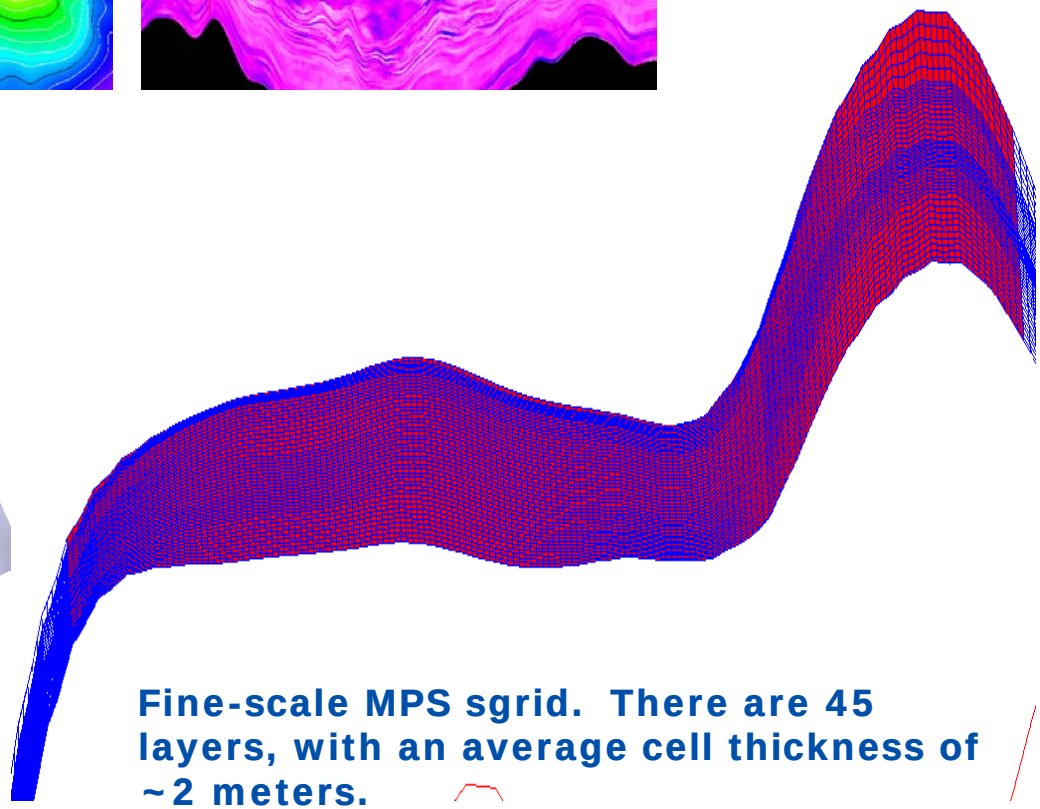
Carbonate MPS/FDM Modeling
Define Region and Layering Scheme







Outline of MPS sgrid;
Areal cell dimensions 50m x 50m

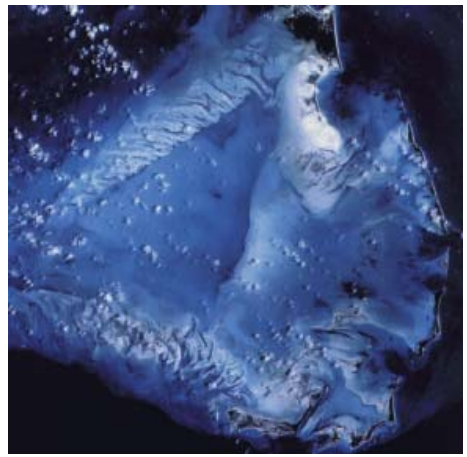


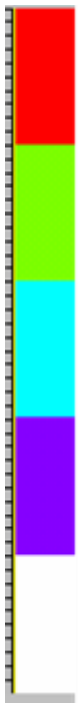
Fine-scale MPS sgrid. There are 45 layers, with an average cell thickness of ~2 meters.

Carbonate MPS/FDM Modeling
Rationale for Training Images

Bashkirian platform top has widespread grainstones.

Some type of bar and flank (channel) morphology is likely.





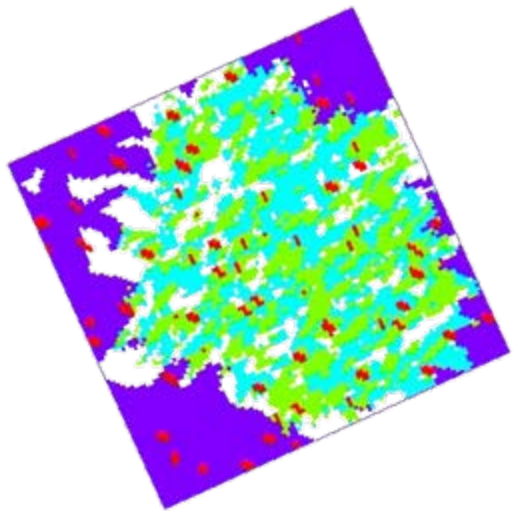
Island = localized areas where permeability is enhanced by dissolution during meteoric diagenesis

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 muddier facies or to porosity-plugging cementation



Carbonate MPS/FDM Modeling
Analogs for Training Images

Bar crest and bar flank grainstone facies of the shallow platform top are modeled as two types -

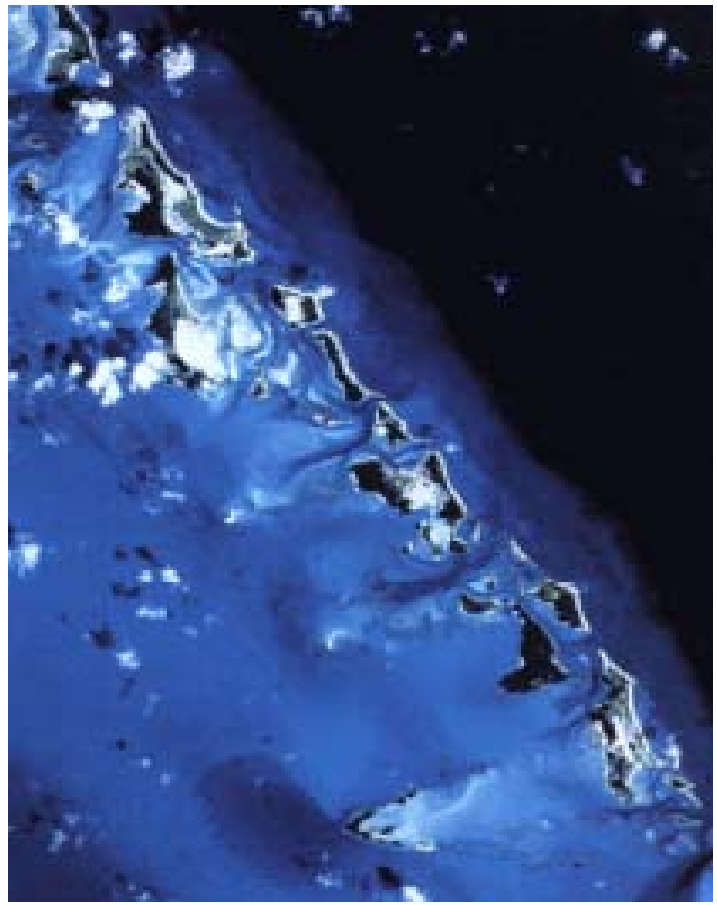
Narrow where bars are long, narrow, and sinuous

Wide where bars are short, wide, and straight

Carbonate MPS/FDM Modeling
Analogs for Training Images

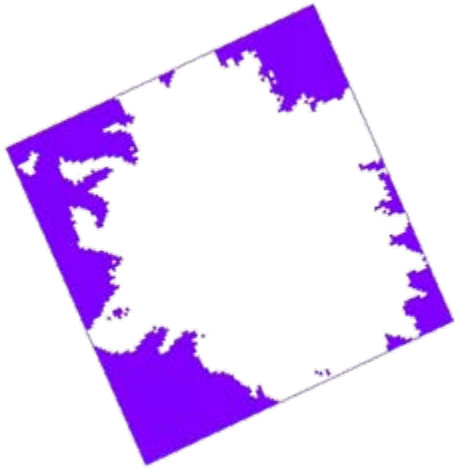
Islands are considered to be a part of the elevated rim that partially surrounds the platform top, especially in the uppermost layers

Islands are long and narrow

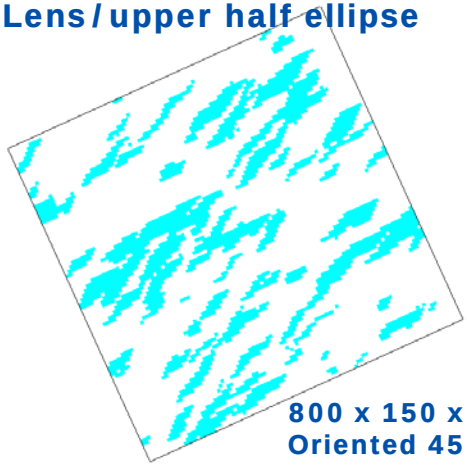


Carbonate MPS/FDM Modeling
Build Single Facies Training Images

Carbonate platform

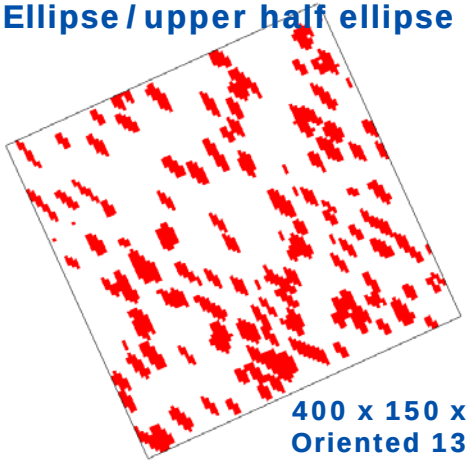


Lens/upper half ellipse



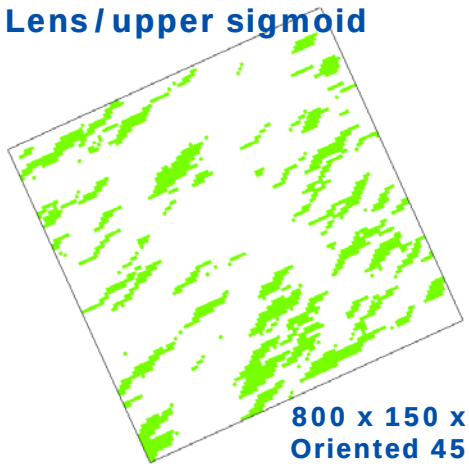
800 x 150 x 6
Oriented 45

Ellipse/upper half ellipse

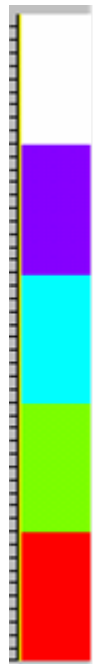


400 x 150 x 3
Oriented 135

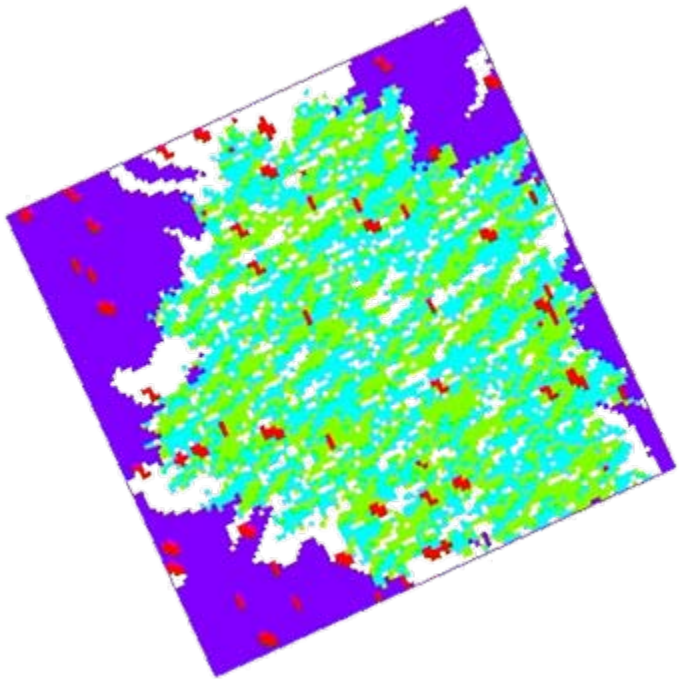
Lens/upper sigmoid



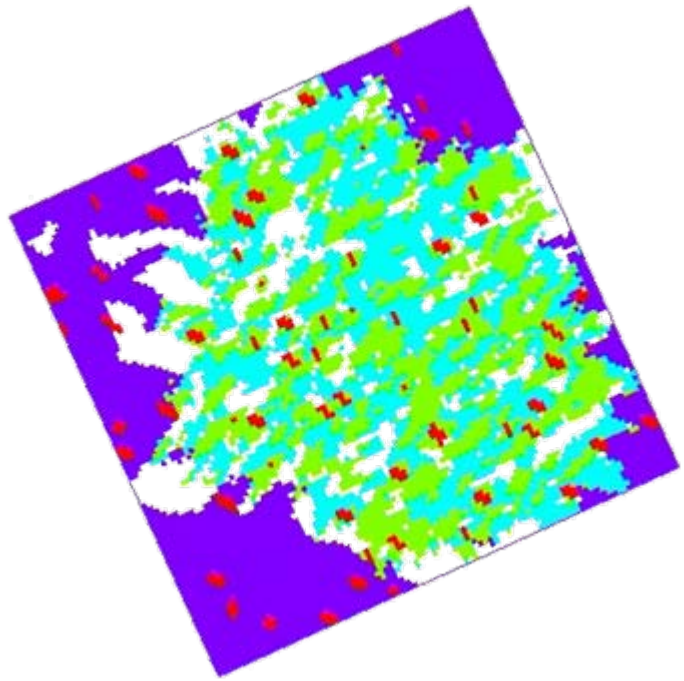
800 x 150 x 6
Oriented 45



Carbonate MPS/FDM Modeling
Build Combined Training Images



Training image using the bar crest narrow and bar flank narrow facies files

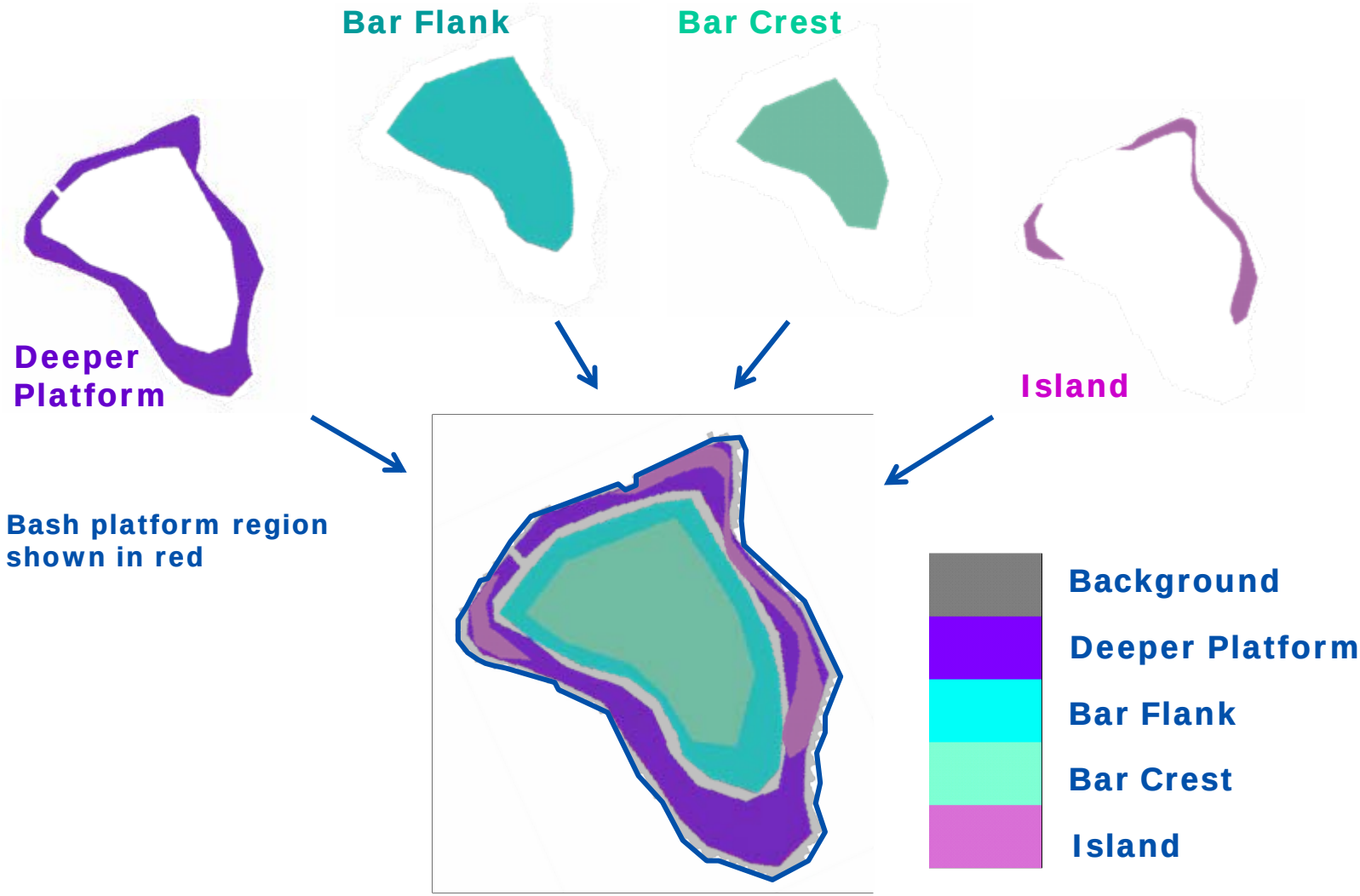


Training image using the bar crest wide and bar flank wide facies files

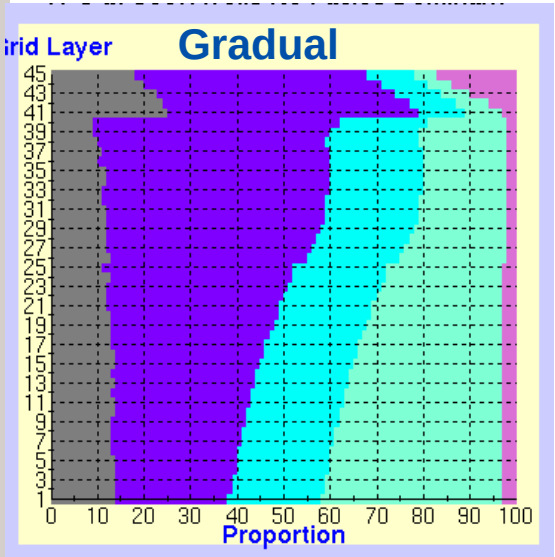
Note: Training images contain no absolute spatial information

bkgrd | deeper platform | bar flank | bar crest | island

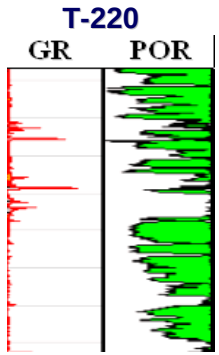
Carbonate MPS/FDM Modeling
Facies Depocenter Maps

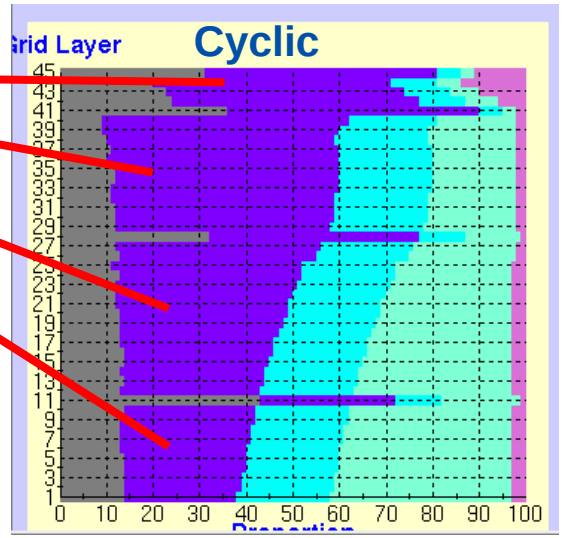


Carbonate MPS/FDM Modeling
Create Vertical Proportion Curves

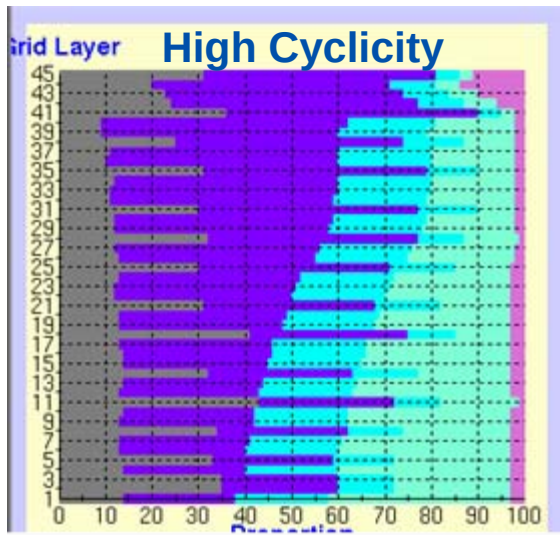


Global Facies Proportions:
0: 13; 1: 40; 2: 19; 3: 25; 4: 3





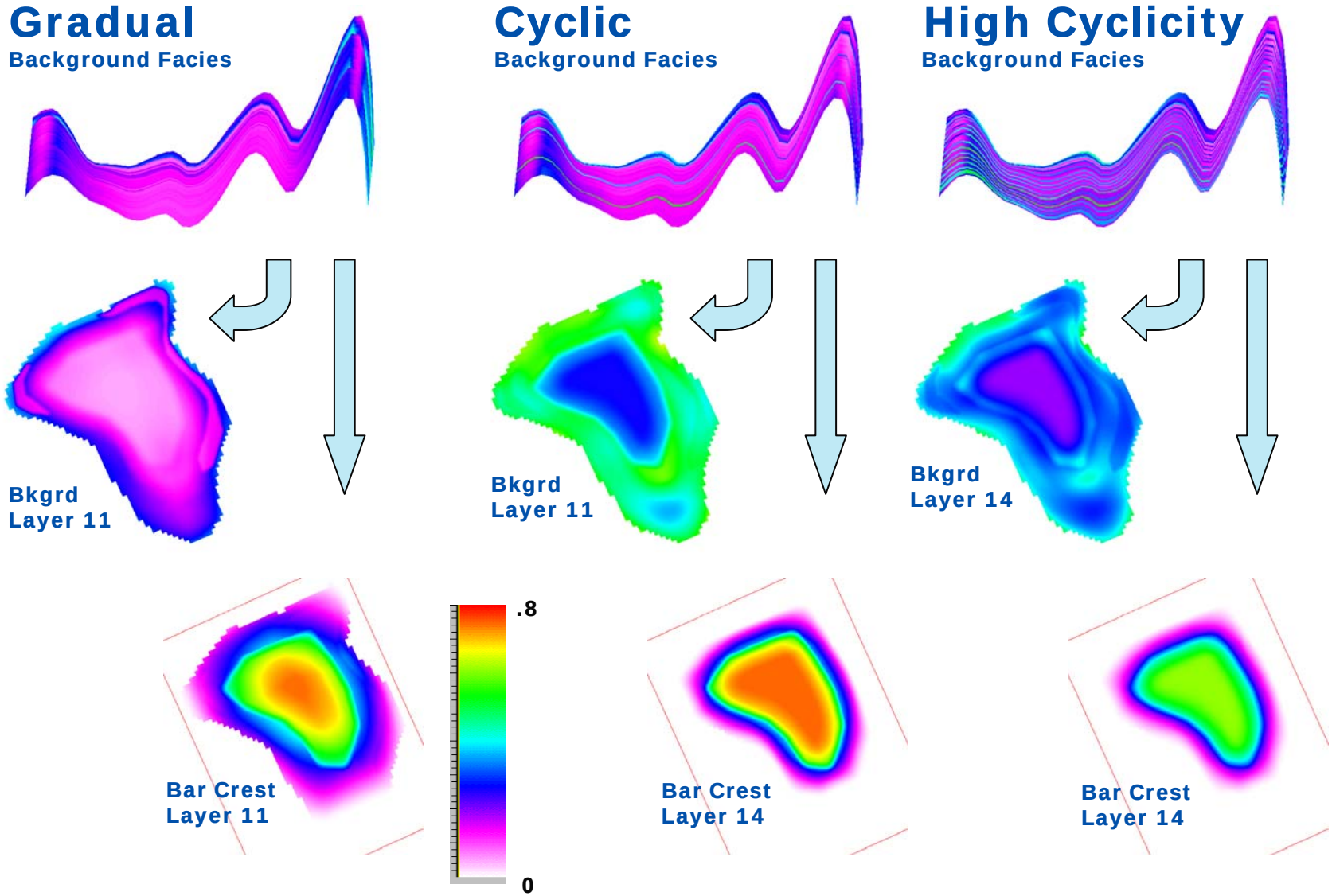
Global Facies Proportions:
0: 15; 1: 40; 2: 18; 3: 24; 4: 3



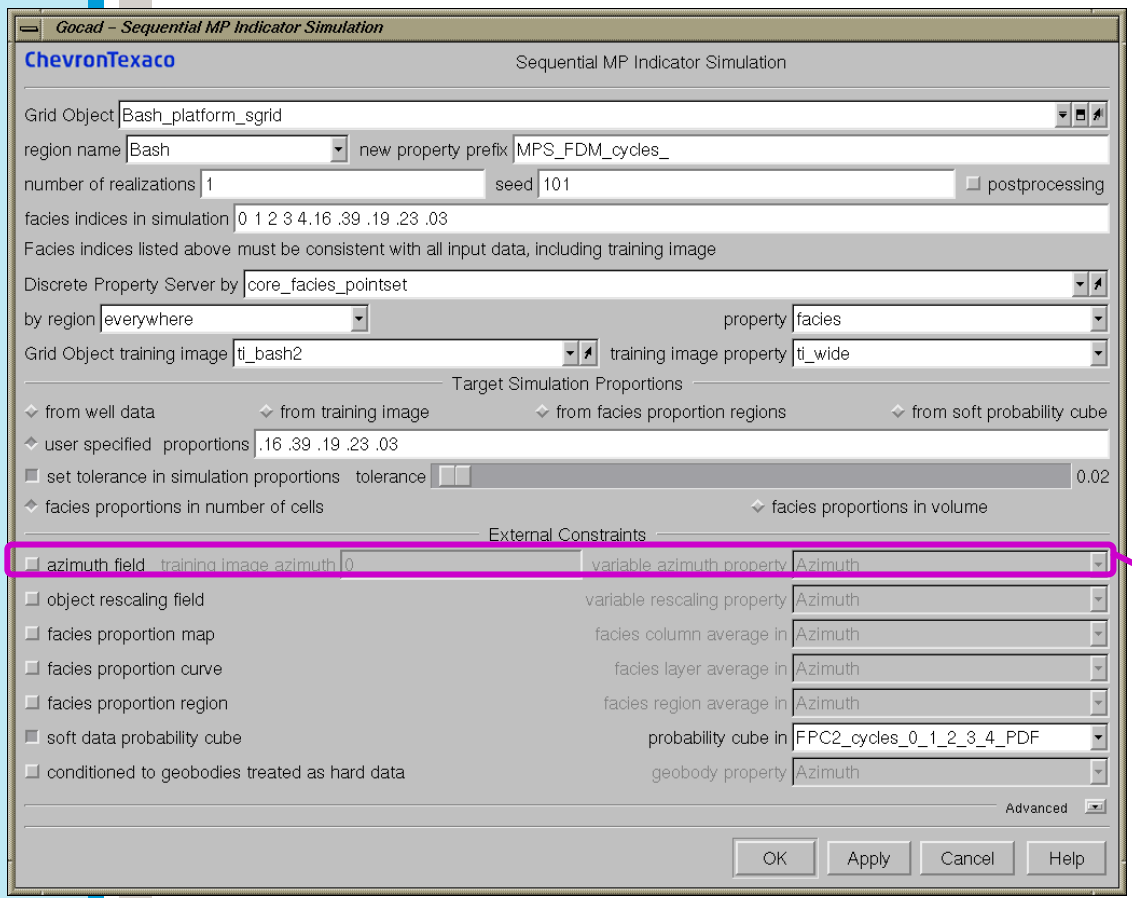
Global Facies Proportions:
0: 20; 1: 40; 2: 16; 3: 21; 4: 3

0	Background
1	Deeper Platform
2	Bar Flank
3	Bar Crest
4	Island

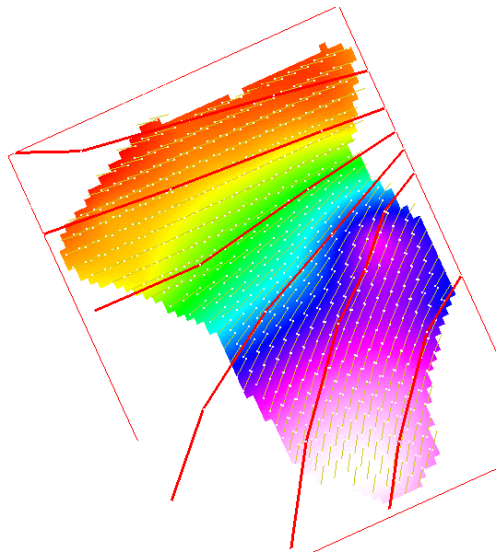
Carbonate MPS/FDM Modeling
Generate Facies Probability Cubes



Carbonate MPS/FDM Modeling
Add External Constraint

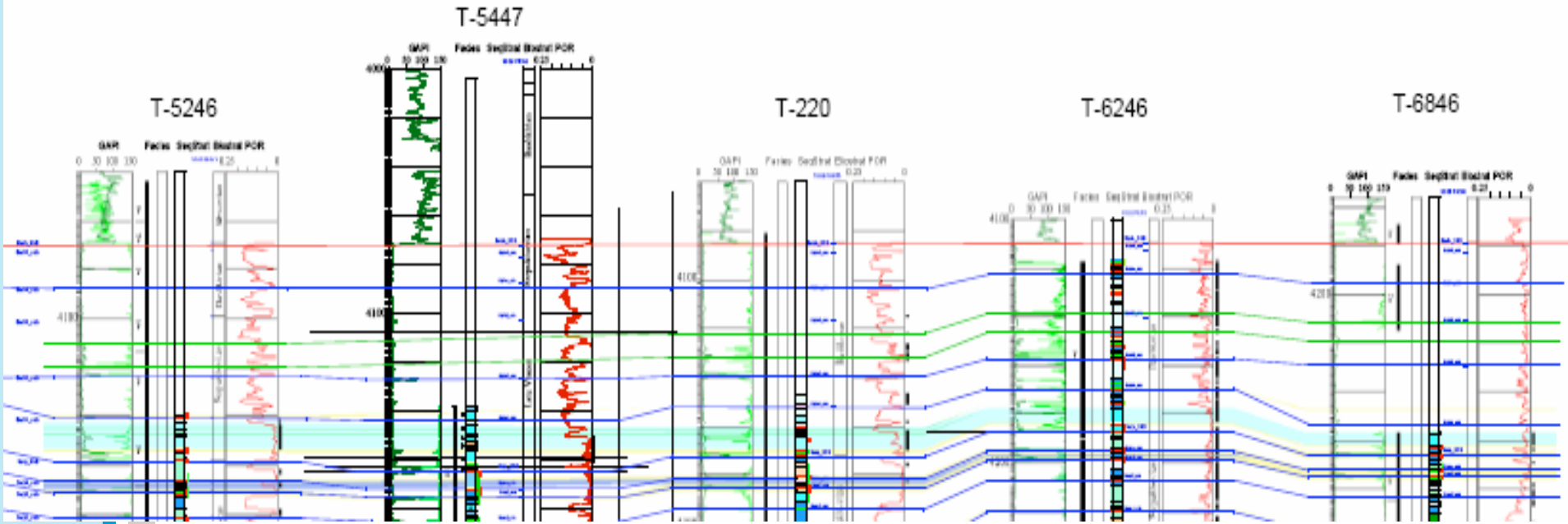


MPS simulation can be modified with external constraints such as the variable azimuth map shown below



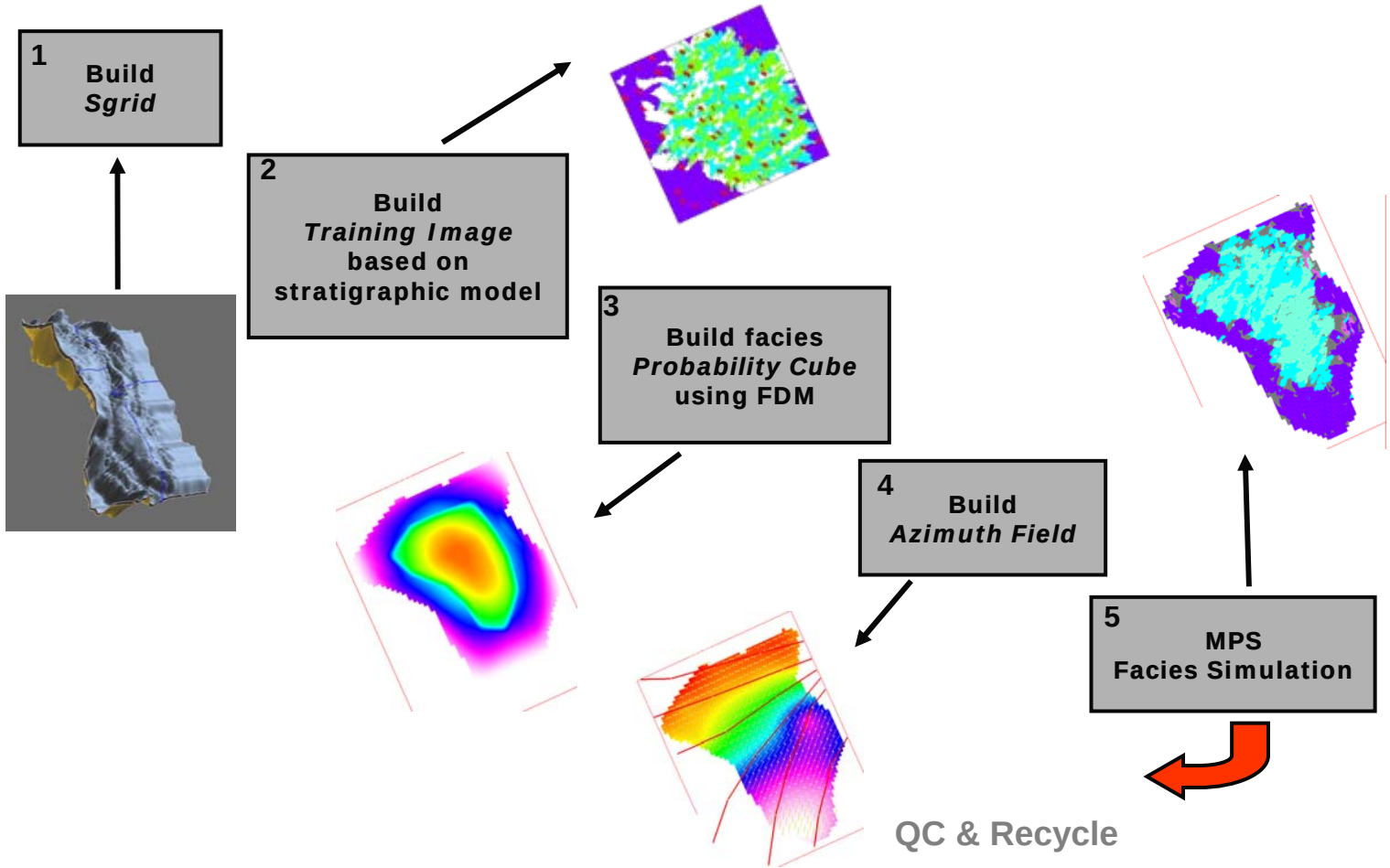
Carbonate MPS/FDM Modeling
Control from Cored Wells

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



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

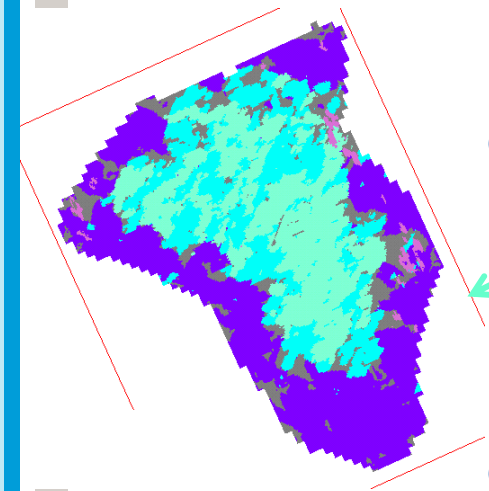
Carbonate MPS/FDM Modeling Workflow

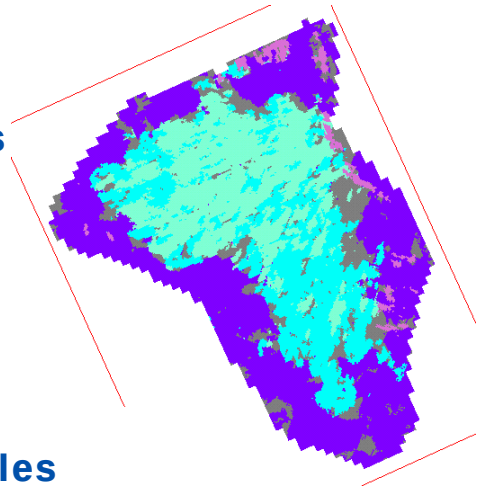


Carbonate MPS/FDM Modeling
MPS Simulation – Map View

Constant Azimuth Field

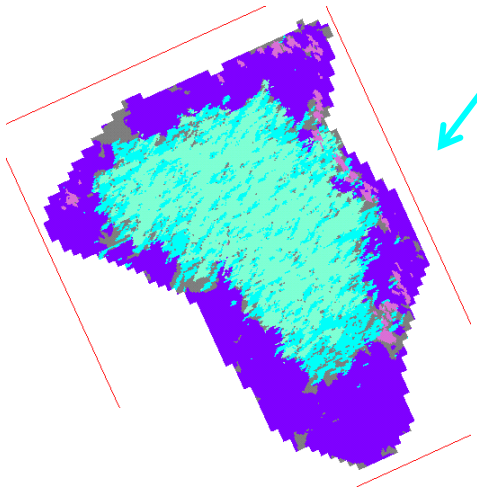
Variable Azimuth Field

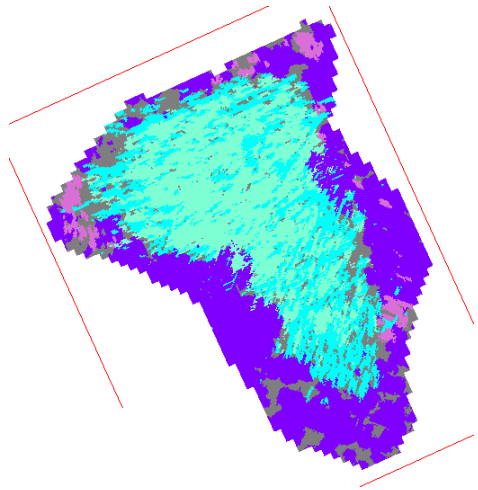




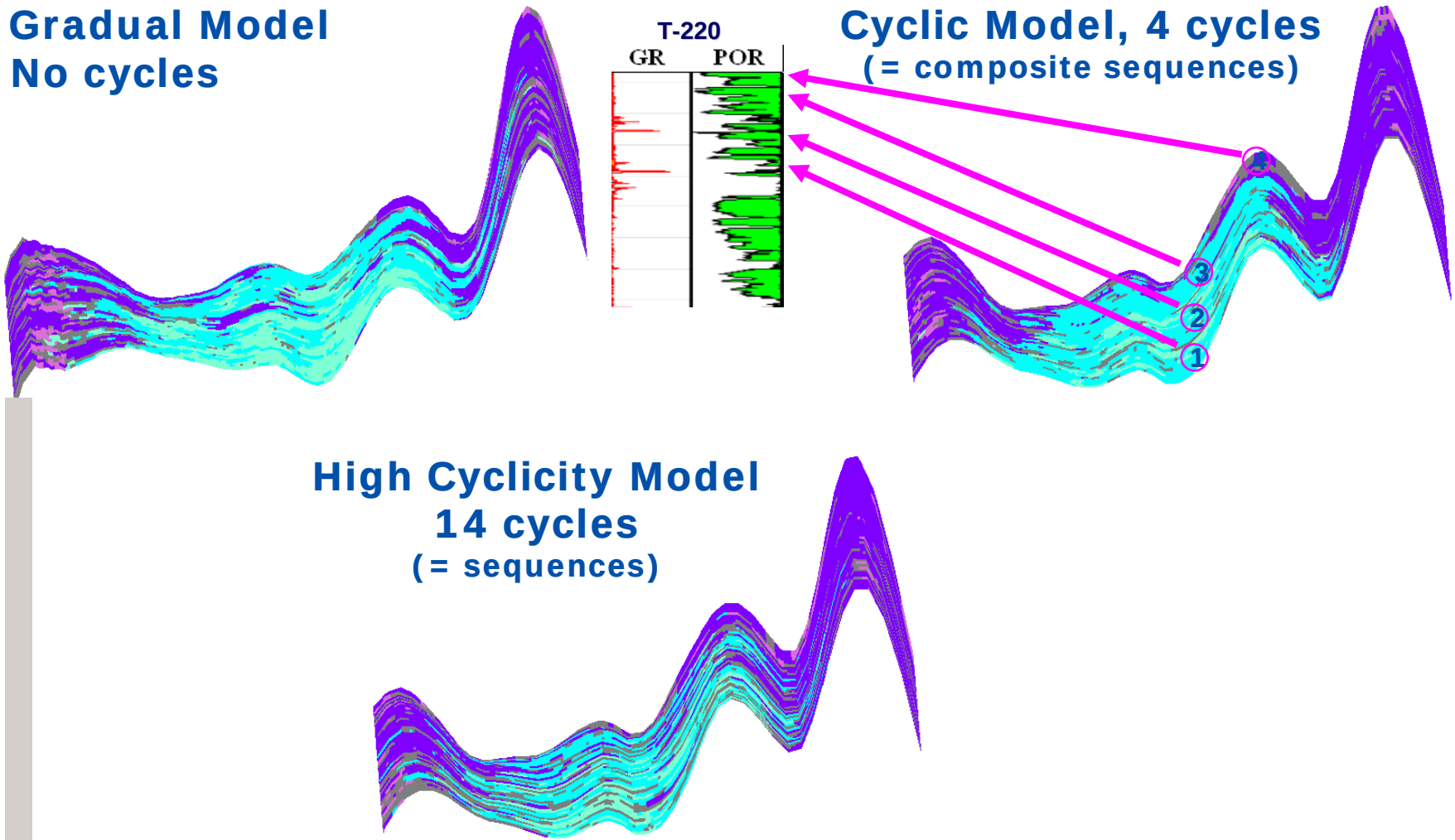
MPS simulation using wide bar crest and wide bar flank facies files

MPS simulation using narrow bar crest and narrow bar flank facies files



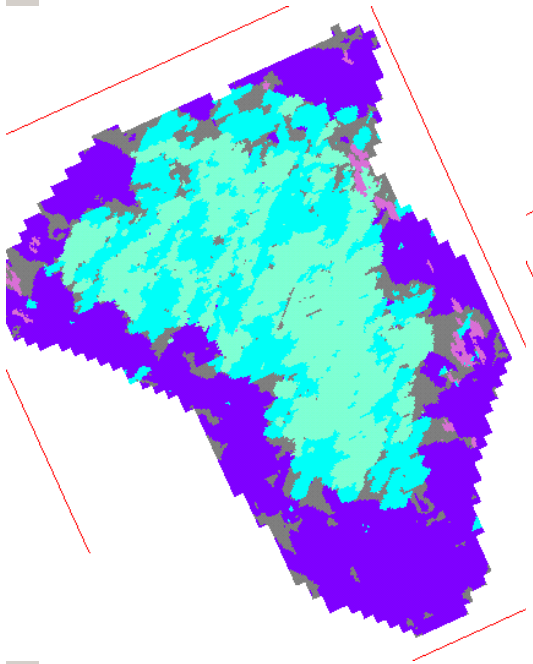


Carbonate MPS/FDM Modeling
MPS Simulation – Cross-Sectional View

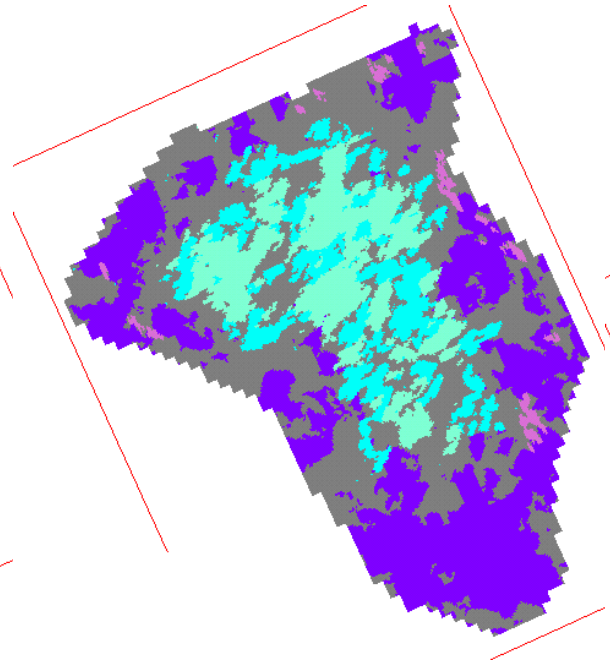


Carbonate MPS/FDM Modeling

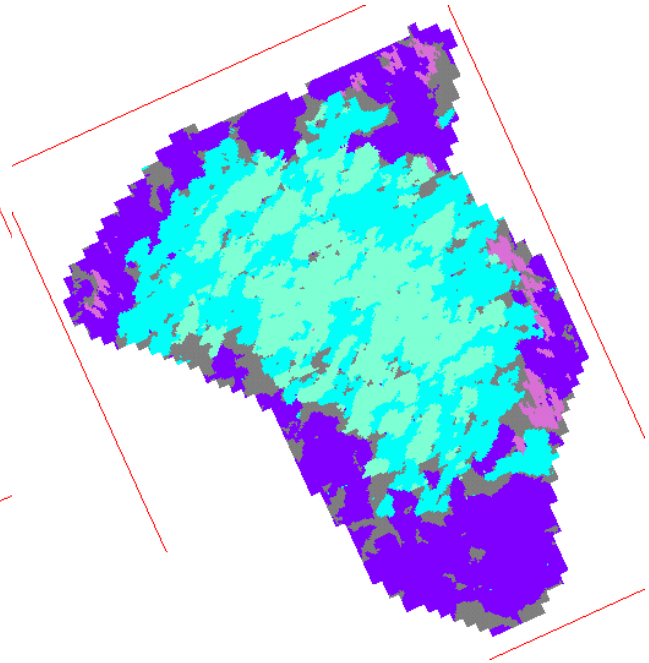
Wide Barcrest/Barflank, High Cyclicity Model



Layer 17:
The central platform is dominated by bar crest and bar flank facies



Layer 18:
background facies impinges on deeper platform and barcrest/barflank facies

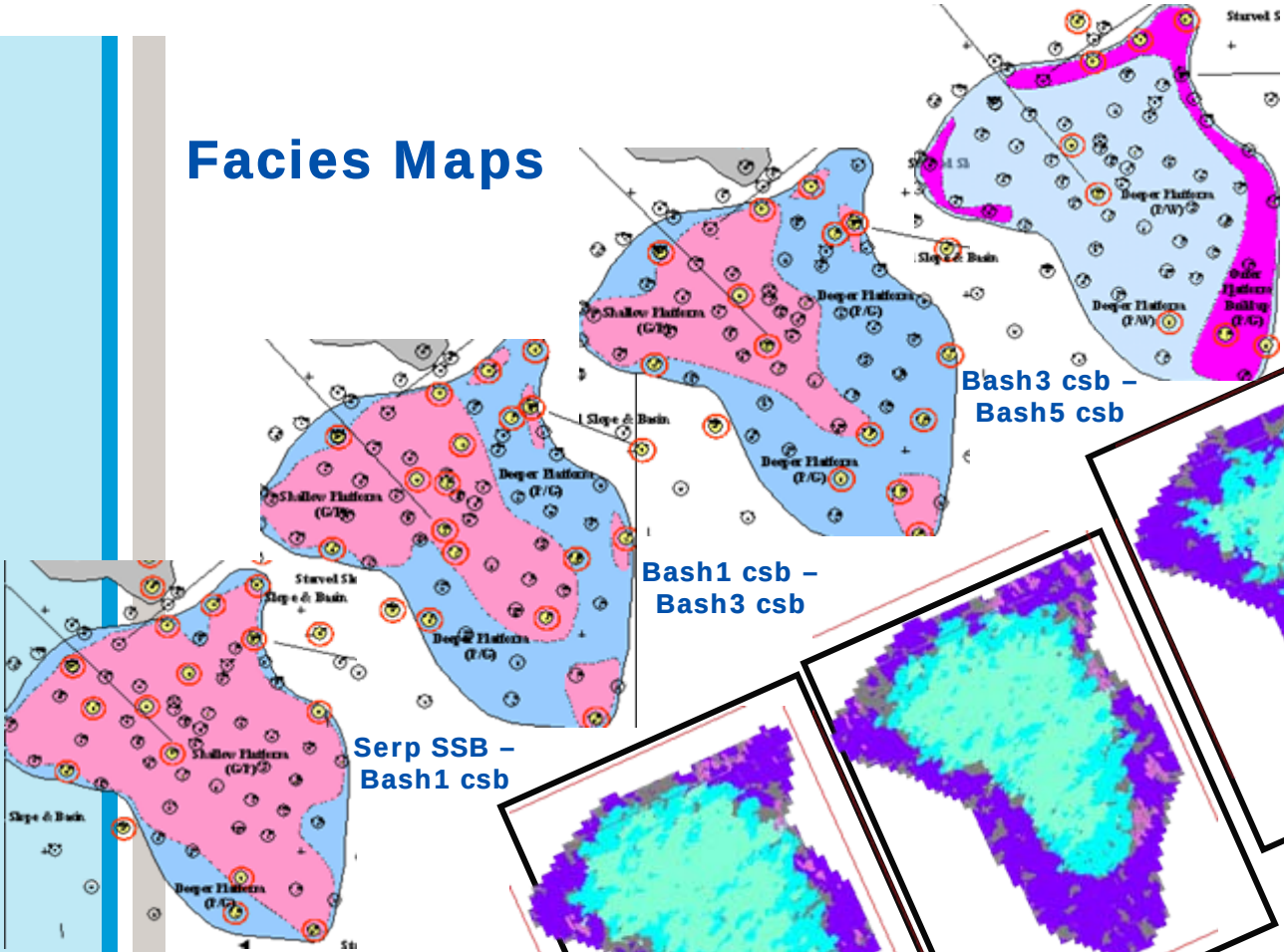


Layer 19:
barcrest/barflank facies return

Carbonate MPS/FDM Modeling

Comparison of Facies Maps with MPS Simulation

Facies Maps

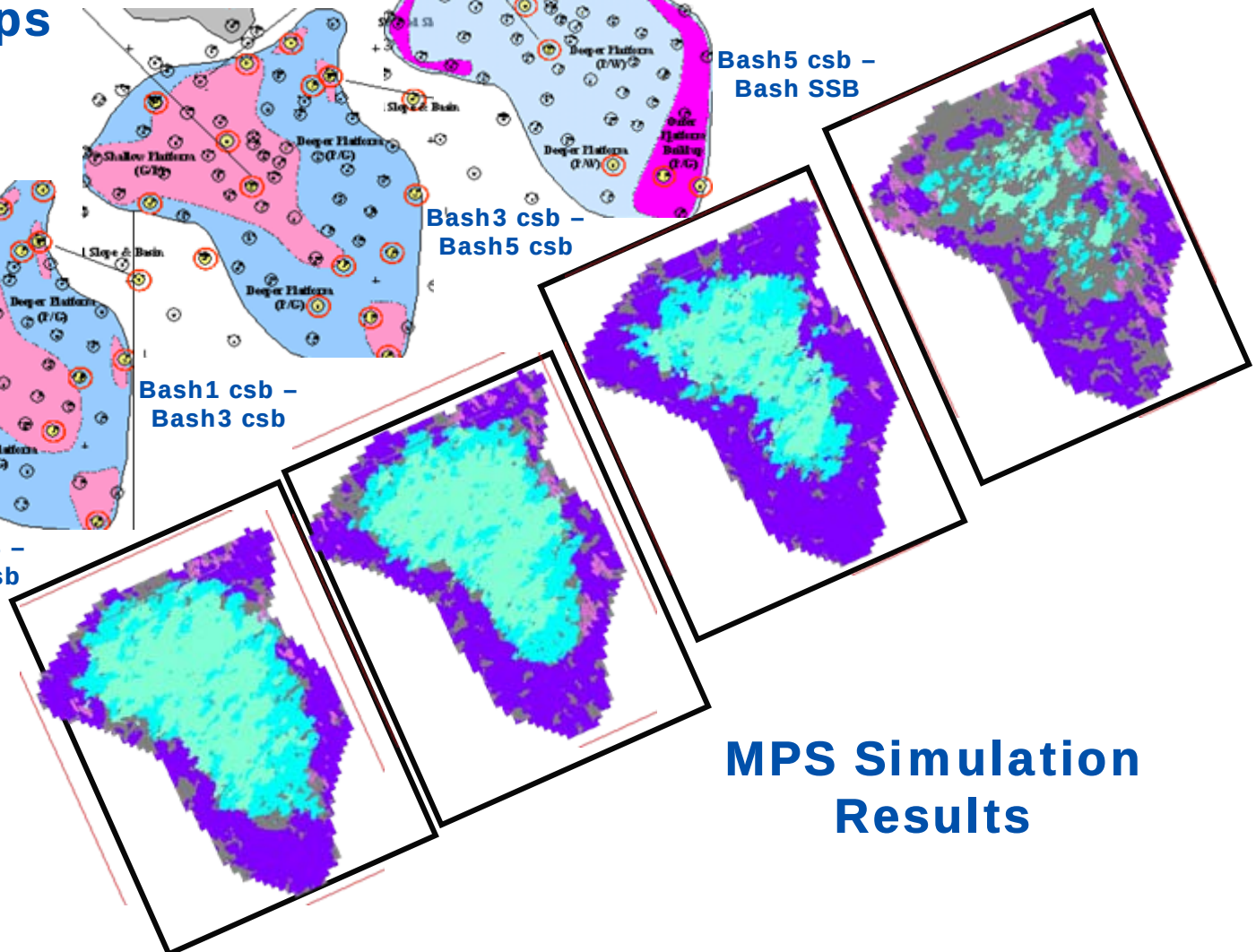


Serp SSB – Bash1 csb

Bash1 csb – Bash3 csb

Bash3 csb – Bash5 csb

Bash5 csb – Bash SSB



MPS Simulation Results

Carbonate MPS/FDM Modeling
Outline

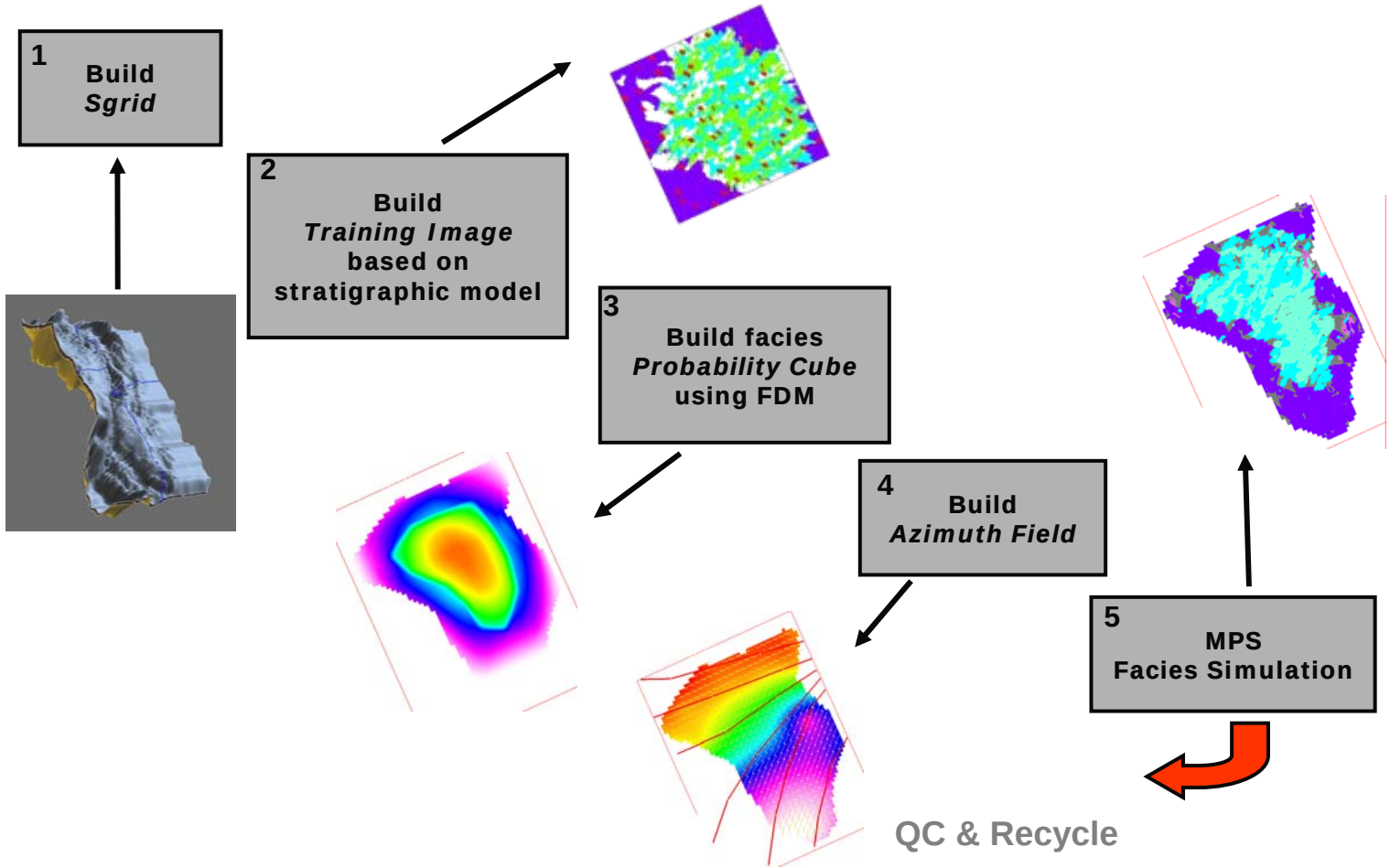
Rationale for Modeling

Introduction to Case Study

MPS/FDM Modeling Steps and Results

Discussion

Carbonate MPS/FDM Modeling
Summary of Matches to Real Data

- Matches facies regions of platform top which were defined during sequence stratigraphy framework development
- Matches stratigraphic variation defined during sequence stratigraphy studes with facies proportion curves
- Matches conceptual models for facies types from modern analogs with training images
- Generally matches facies identified in cored wells

Carbonate MPS/FDM Modeling Workflow