Conditioned Forward Stratigraphic Modeling in Large Carbonate Fields: A Dionisos Model of Karachaganak*

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Abstract

Karachaganak is a large Devonian to Permian age isolated carbonate retrograde gas-condensate field in Northern Kazakhstan. Here, conspicuous steep (20-30 degrees) high-rise (<400 m) clinoforms are observed yet un-mapped due to poor seismic expression, and thus not integrated into the conventional geocellular model used for flow simulations. Although sufficiently simulating field-scale behavior and long-term production, this approach inadequately addresses individual well-performance as proportional bedding used in the conventional model construction cross-cuts steeply dipping flow units. Flow-unit orientation is critical as it strongly influences vertical reservoir connectivity, affecting produced-fluid composition which varies vertically in the reservoir. Steeply dipping flow units can also decrease horizontal transmissibility (flow across multiple flow units), leading to lateral variations in pressure which are merely the result of stratigraphy.

To address the above-mentioned challenges, we build a model using 'Dionisos, a diffusion-based forward stratigraphic modeling package. Vertical thicknesses are conditioned by stretching the final model to mapped seismic surfaces. Facies are conditioned manually to interpreted facies maps by interval. Equally, geomorphologic elements of platform-top and slope are conditioned to seismic observations. Boundary input parameters, such as model age, eustatic sea level, as well as sediment production rates and depths, correspond to the respective geologic age of the reservoir. The resulting S-grid is populated with depositional facies and captures the non-stationary facies patterns currently difficult to achieve with conventional geostatistical simulations. 3D co-rendering of the Dionisos model and seismic cube has provided a powerful instrument used extensively to re-evaluate the seismic interpretation. We gained valuable insights in particular where model prediction and seismic cube disagree and in areas of poor seismic quality, such as sub-salt environments. Furthermore the model offered alternative scenarios to existing seismic interpretations.

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AAPG International Meeting

October 2008, Cape Town, South Africa

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Models and Models

INPUT

Well data

Seismic data

Geological concepts

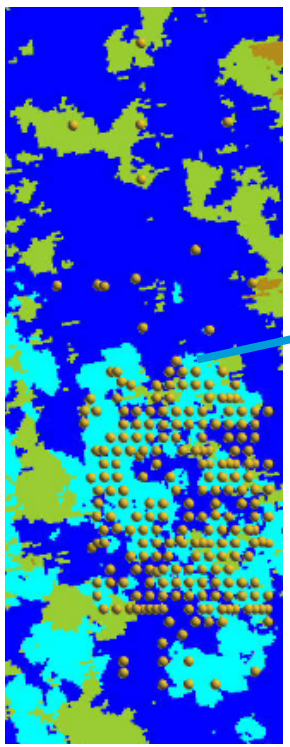
Geostatistical modeling (Gocad, MPS, etc)

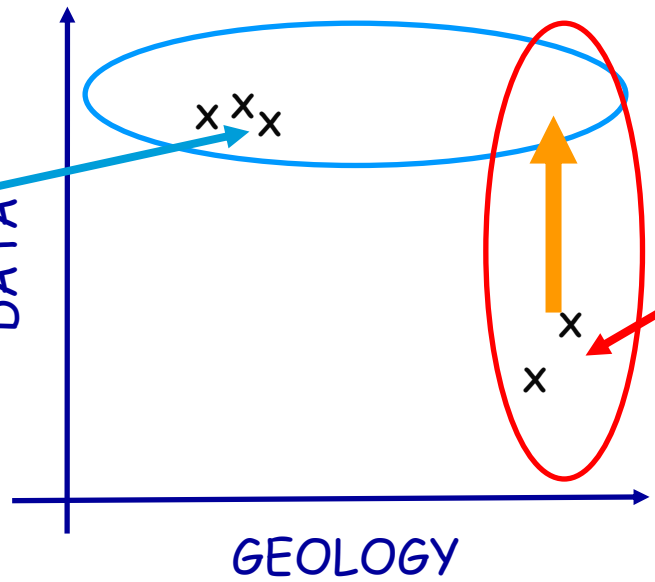
Forward stratigraphic modeling (Dionisos, Carb3d+, etc)

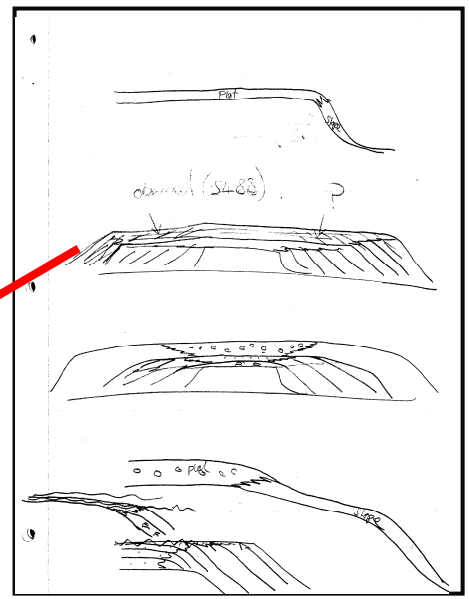
OUTPUT

Geostatistical model
· data conditioned
but not necessarily geological

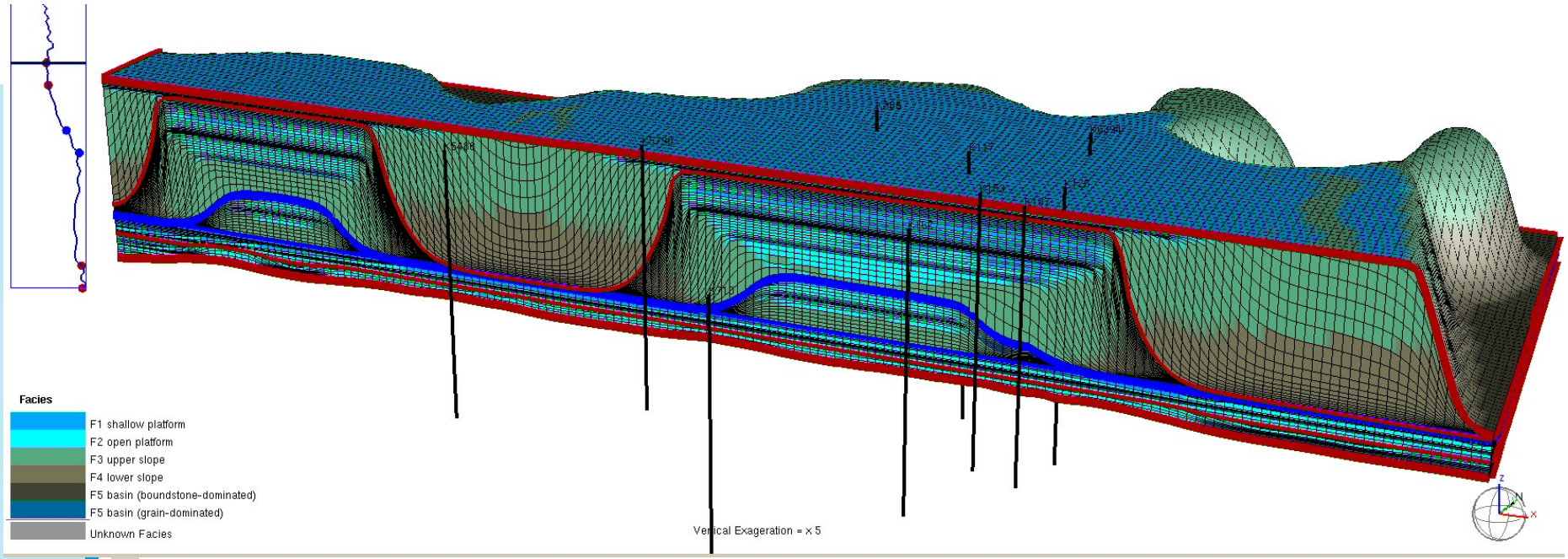
Forward stratigraphic model
· geological appearance
but unconditioned to data







Isolated Carbonate Platform: Case Study



- Rationale
- Forward Stratigraphic Models
- Base Case Model
- Interrogation of Base Case Model
- Revision
- Potential Applications

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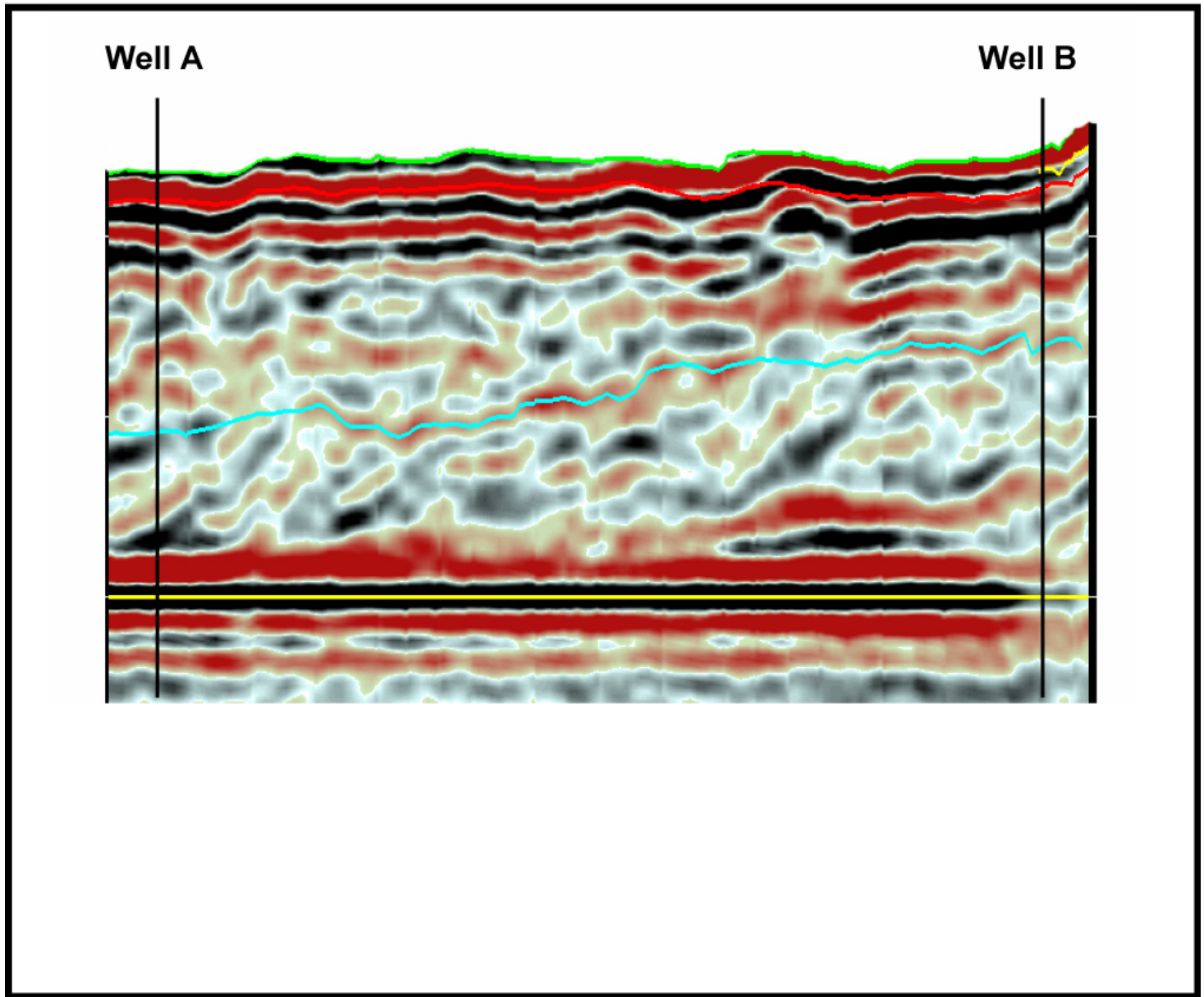
Well Connectivity



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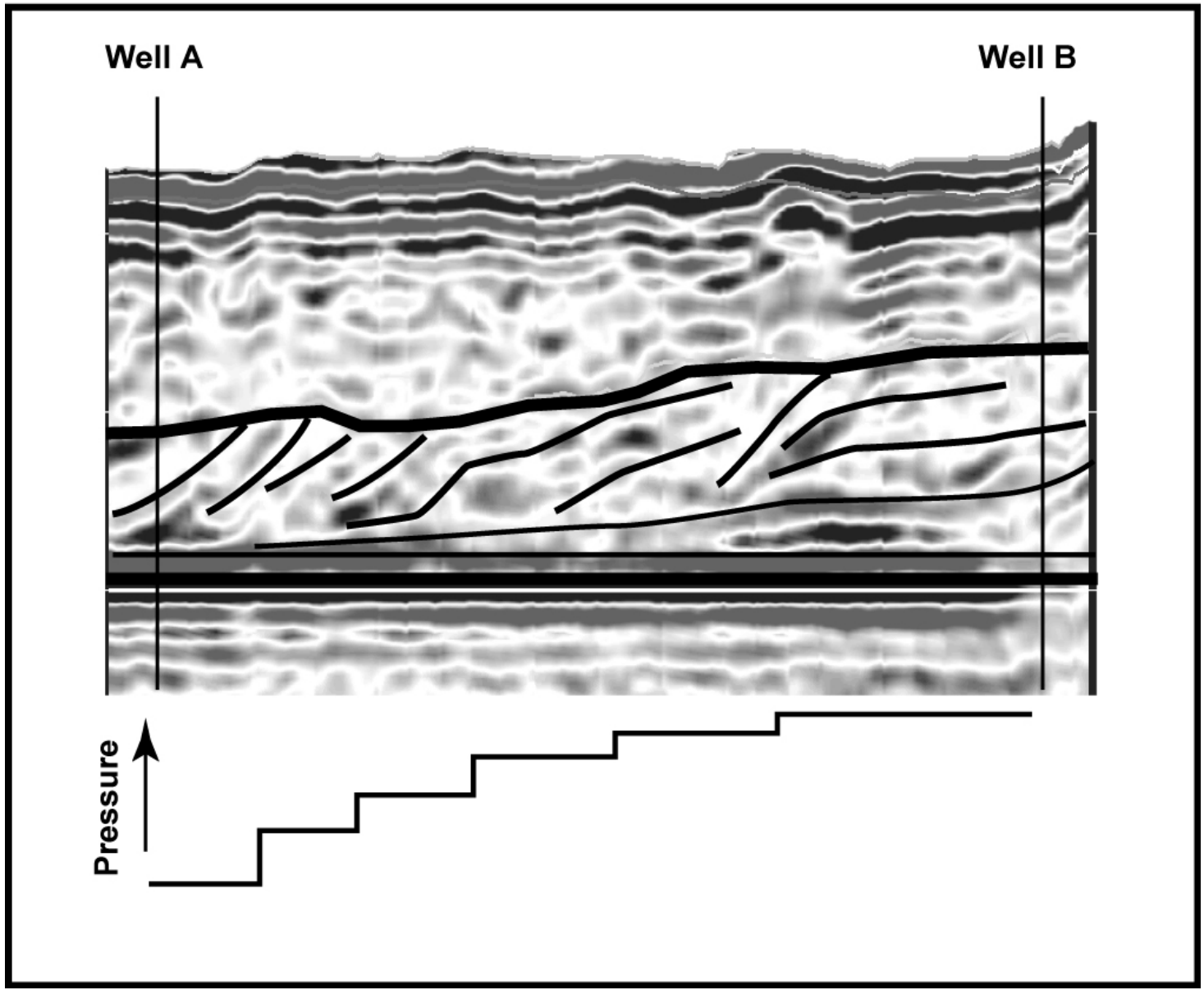
Importance of Preserving Steep-Angled Slopes in the Model



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Forward Stratigraphic Modeling (FSM)

Numerical simulation of the sedimentological processes that produce stratigraphy.

Numerous modeling software packages available; each with a distinct specialty (i.e. time and spatial scale, geologic setting etc.).

DIONISOS

Diffusive **O**rientated **N**ormal and **I**nverse **S**imulation of **S**edimentation

by IFP *(Granjeon, 1997; Granjeon and Joseph, 1999)*

- diffusion-based, multi-lithology, 3D simulator for the use of basin to sub-basin scale over millions of years
- open structure which can model clastics, carbonates, mixed systems, deep water, slope processes, etc
- will not model individual objects (i.e. sand bars)

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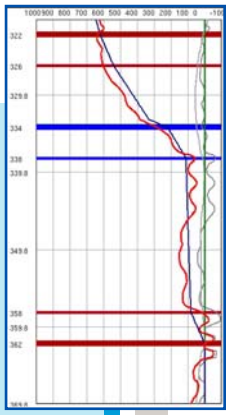
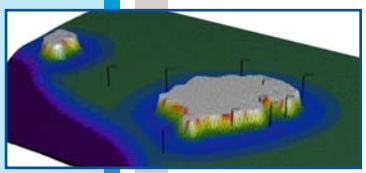
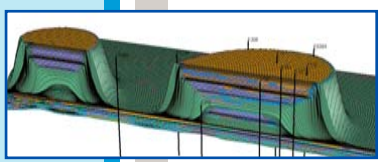
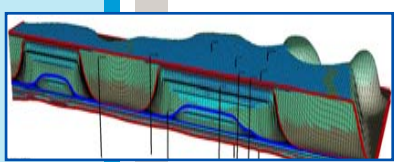
FSM Workflow









1. Choosing critical input parameters

- rate of subsidence -> accommodation space
- rate of sea level change -> accommodation space
- sediment production rates -> strata thickness
- hydrodynamic regime -> sediment distribution
- model dimensions, time step; model space
- conditioning of facies and geomorphologic elements

2. Build initial model and perform sensitivity analysis

- identify critical parameters and their effect on model

3. Build, interrogate and revise base model

- comparison to data (seismic and facies at wells)
- model reruns to fine tune facies match

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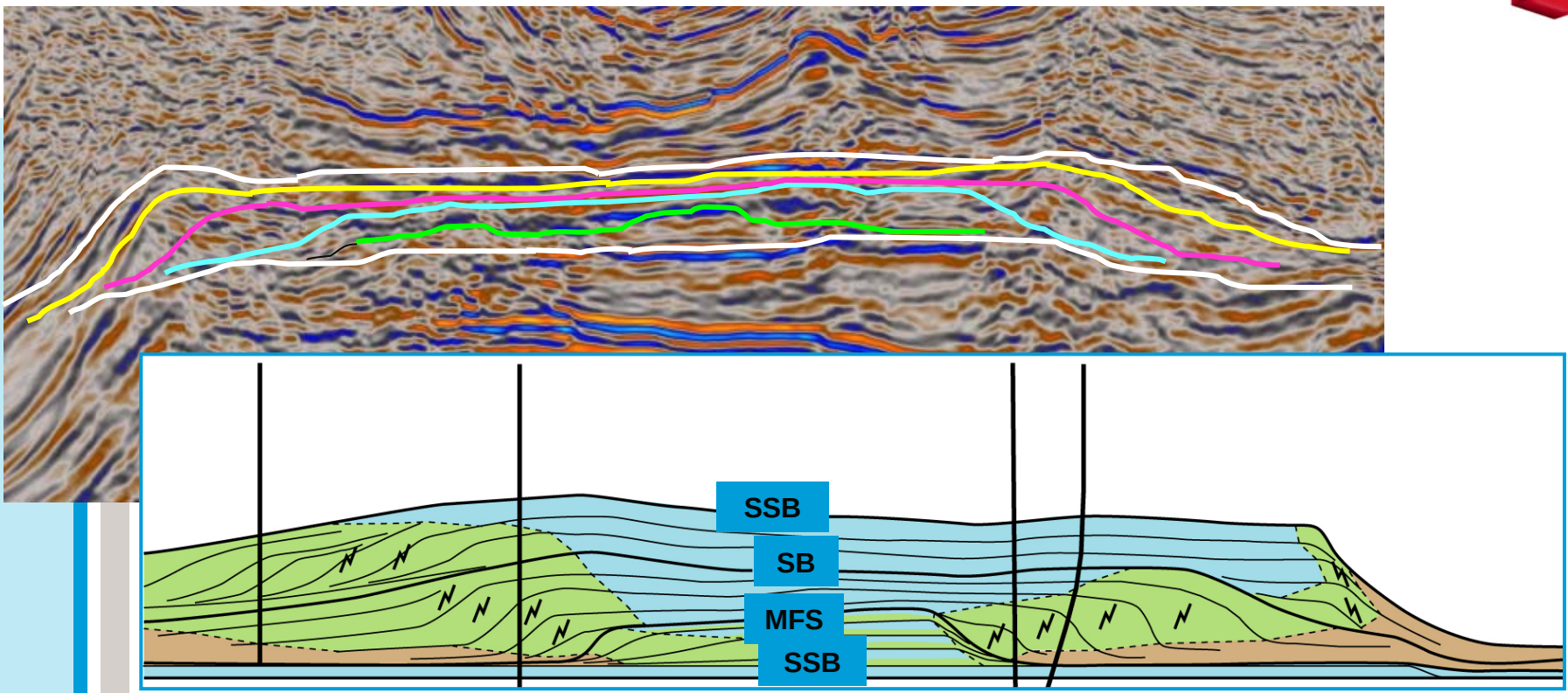
Base Model Inputs



- *Match layer thickness derived from seismically mapped surfaces*
- *Manually match to facies maps for each interval*

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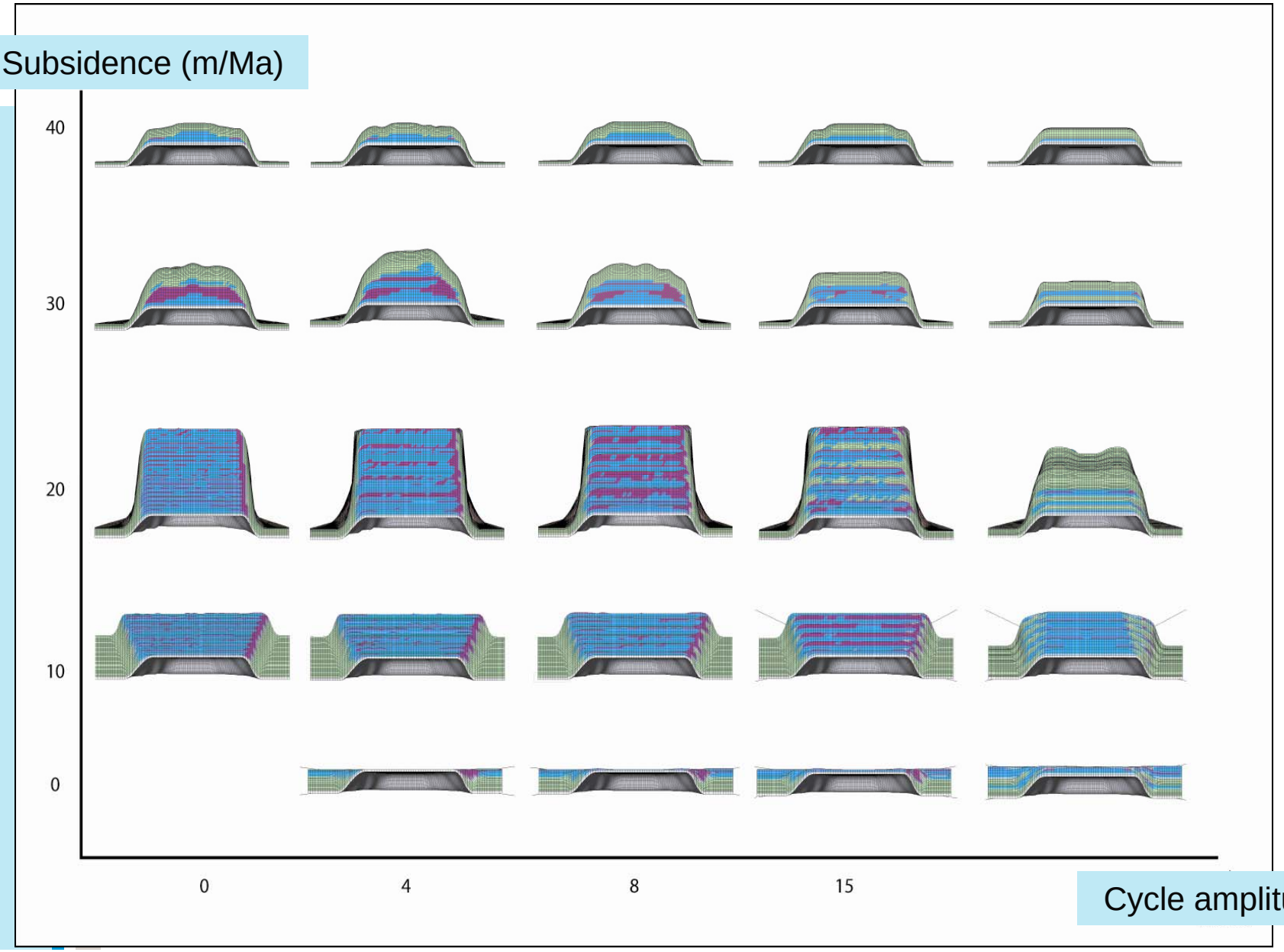
Sensitivity Analysis



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Bassant and Harris, 2007

Base Model Interrogation

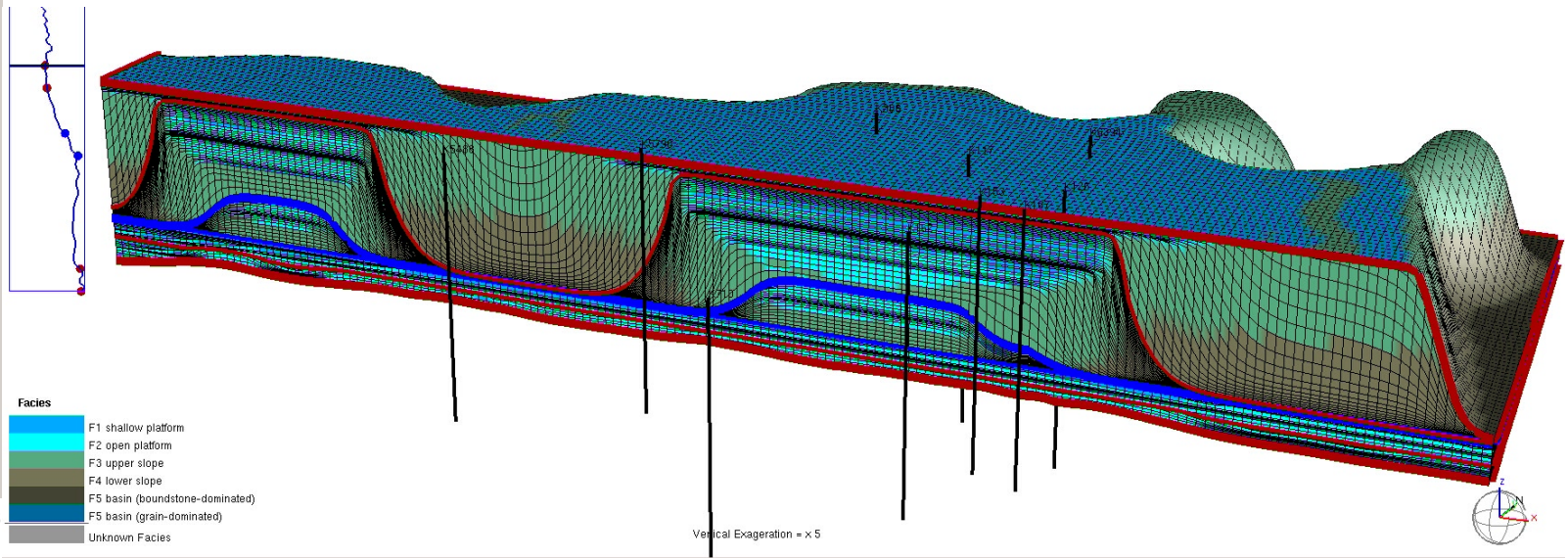
1. Test geological validity of the model by comparison of:

- facies at wells
- observed seismic geometries
- internal consistency check between facies and bedding architecture

2. Decide whether the model is:

- geologically valid as is,
- needs some minor updates before use,
- or belongs in the bin.

3. Revise base model.



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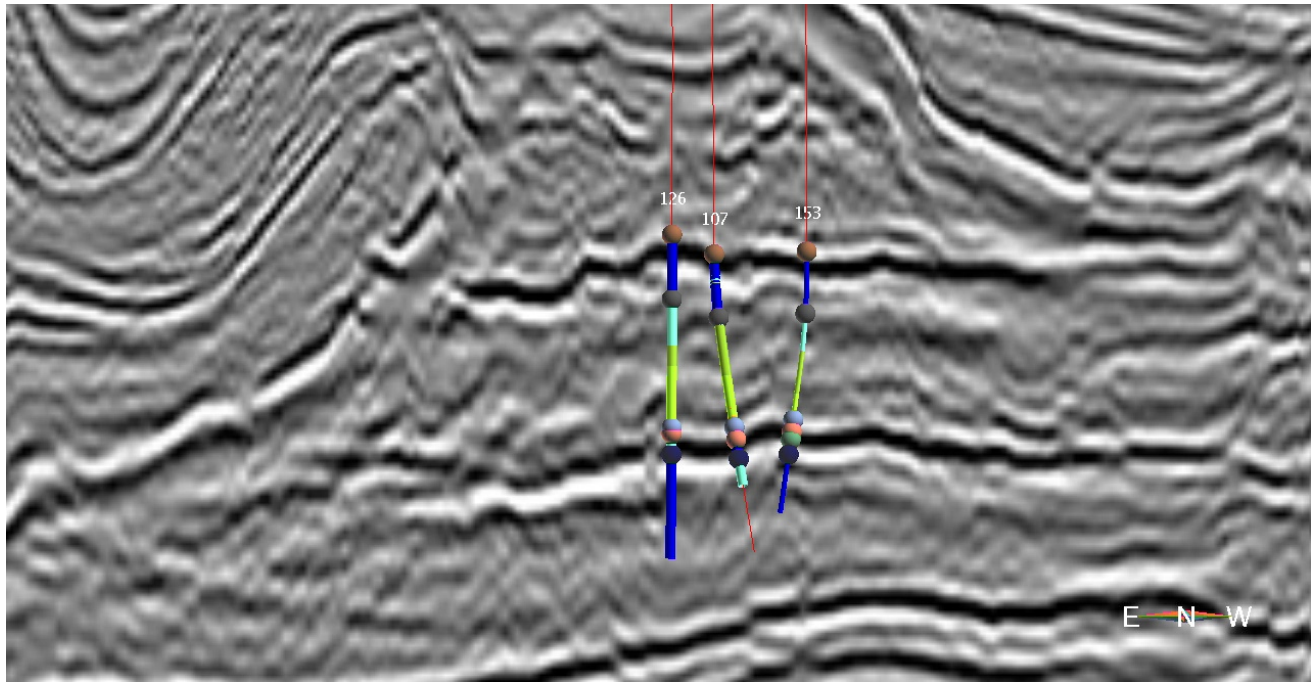
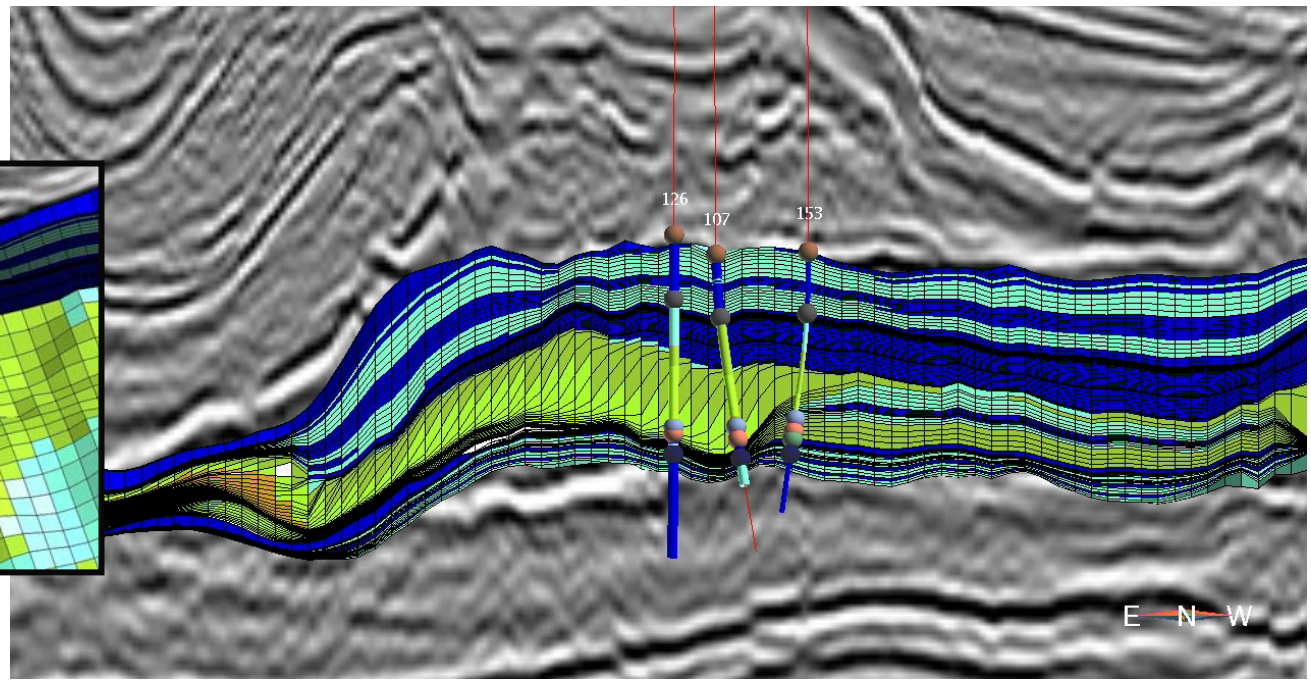
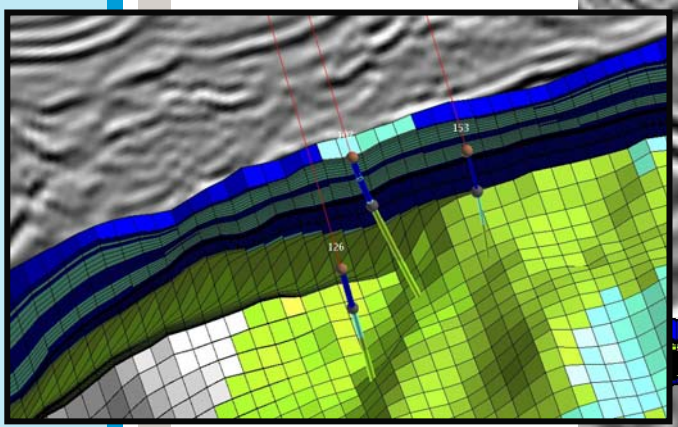
Model Output: Comparison to Seismic and Well Facies







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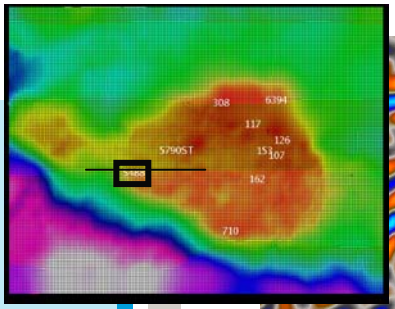
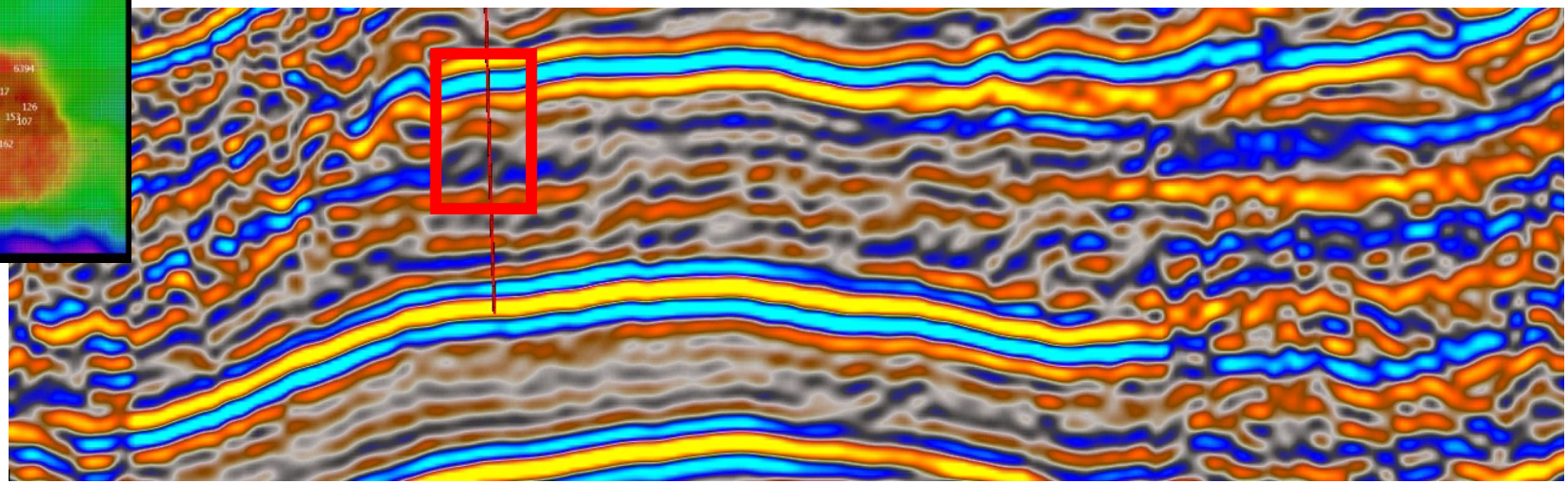
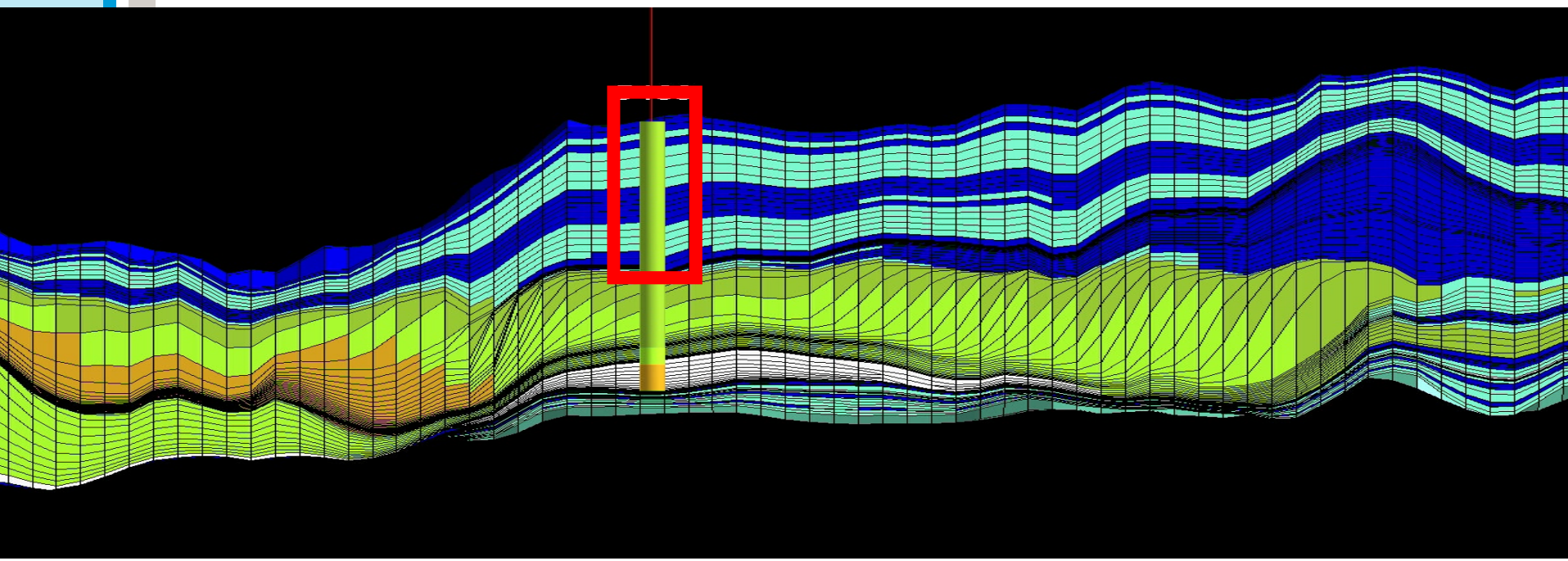
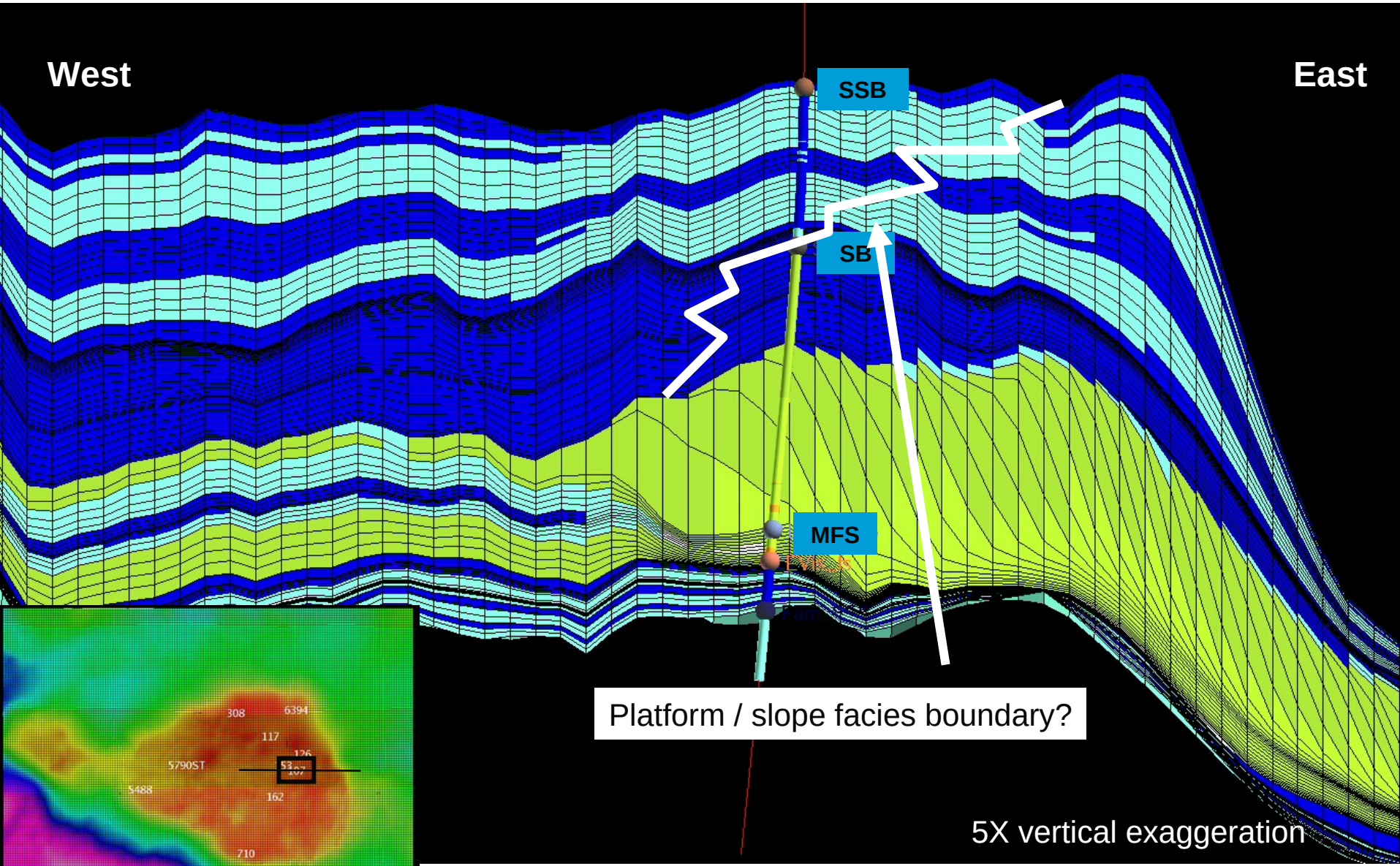
Model Output: Comparison to Seismic and Well Facies



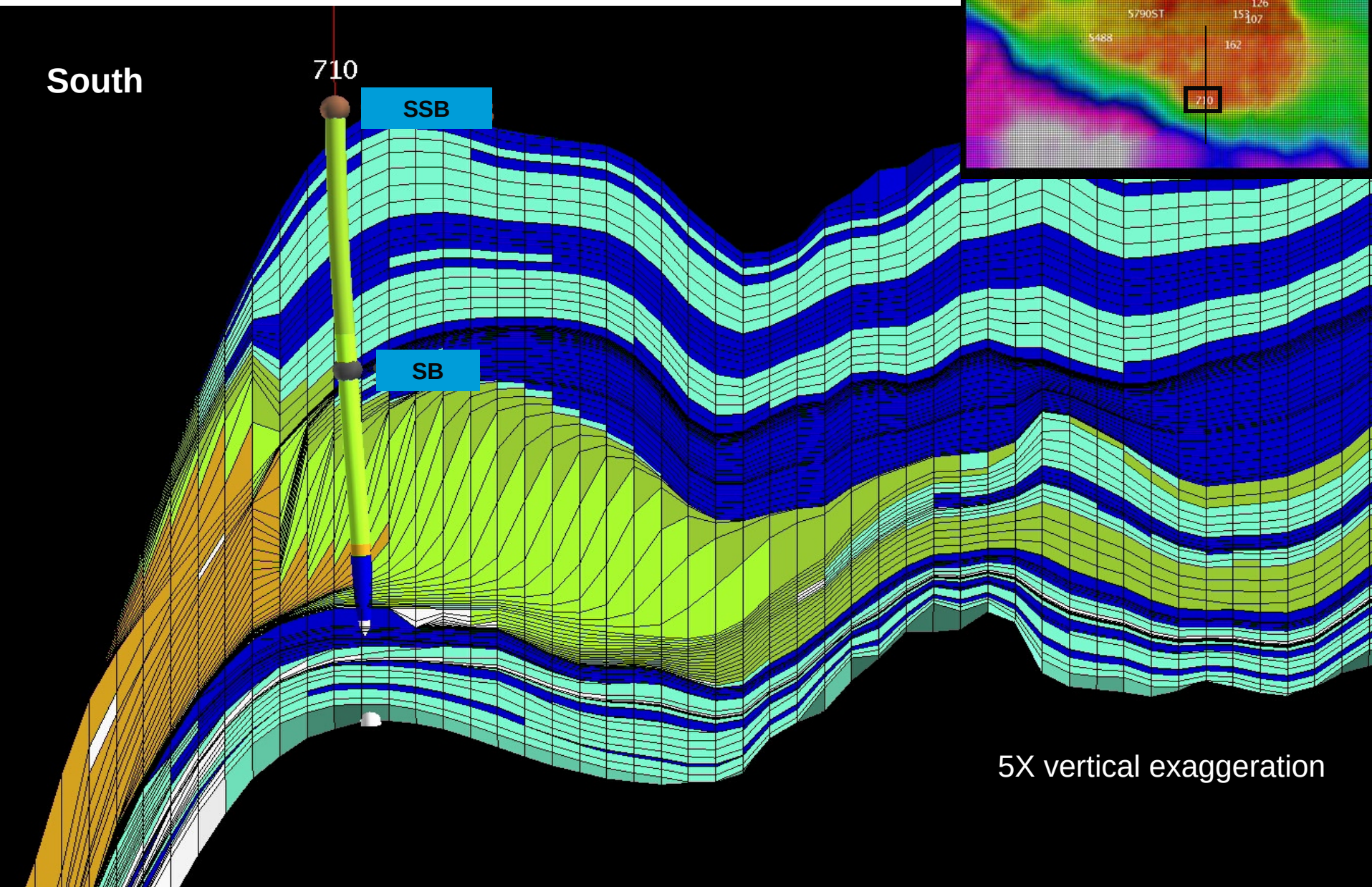


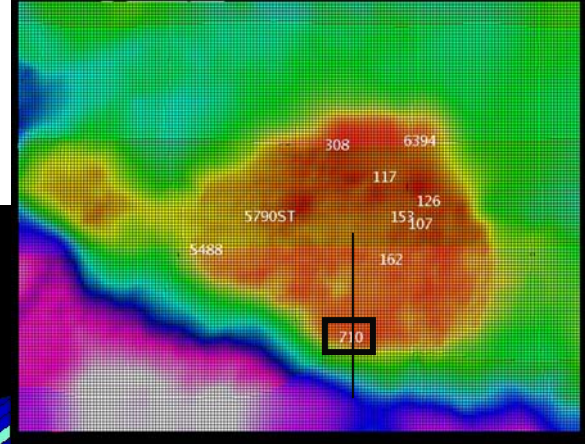


Model Output: Comparison to Well Facies

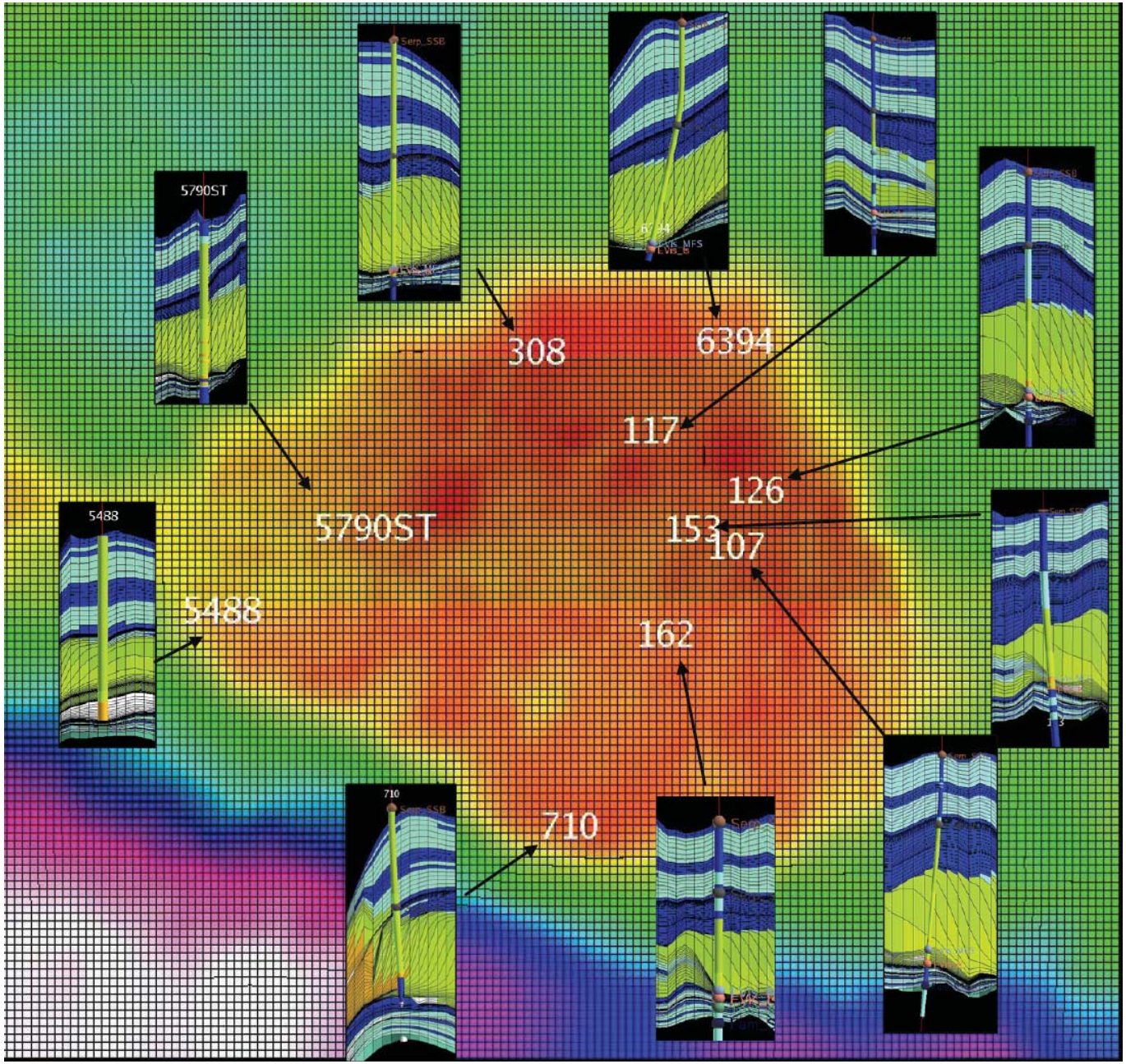


Model Output: Comparison to Well Facies





Slope Comparison



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Model Interrogation Summary

1. Test the geological validity of the model by comparing with:

- facies at wells
- observed seismic geometries
- internal consistency check between facies and bedding architecture

> overestimation of shallow-water platform

> significantly more slope facies needed

> variable clinoform dips

> in need of alternative progradation style

2. Decide whether the model is:

- geologically valid as is,
- needs updating before use,
- or belongs in the bin.

3. Revise base model.

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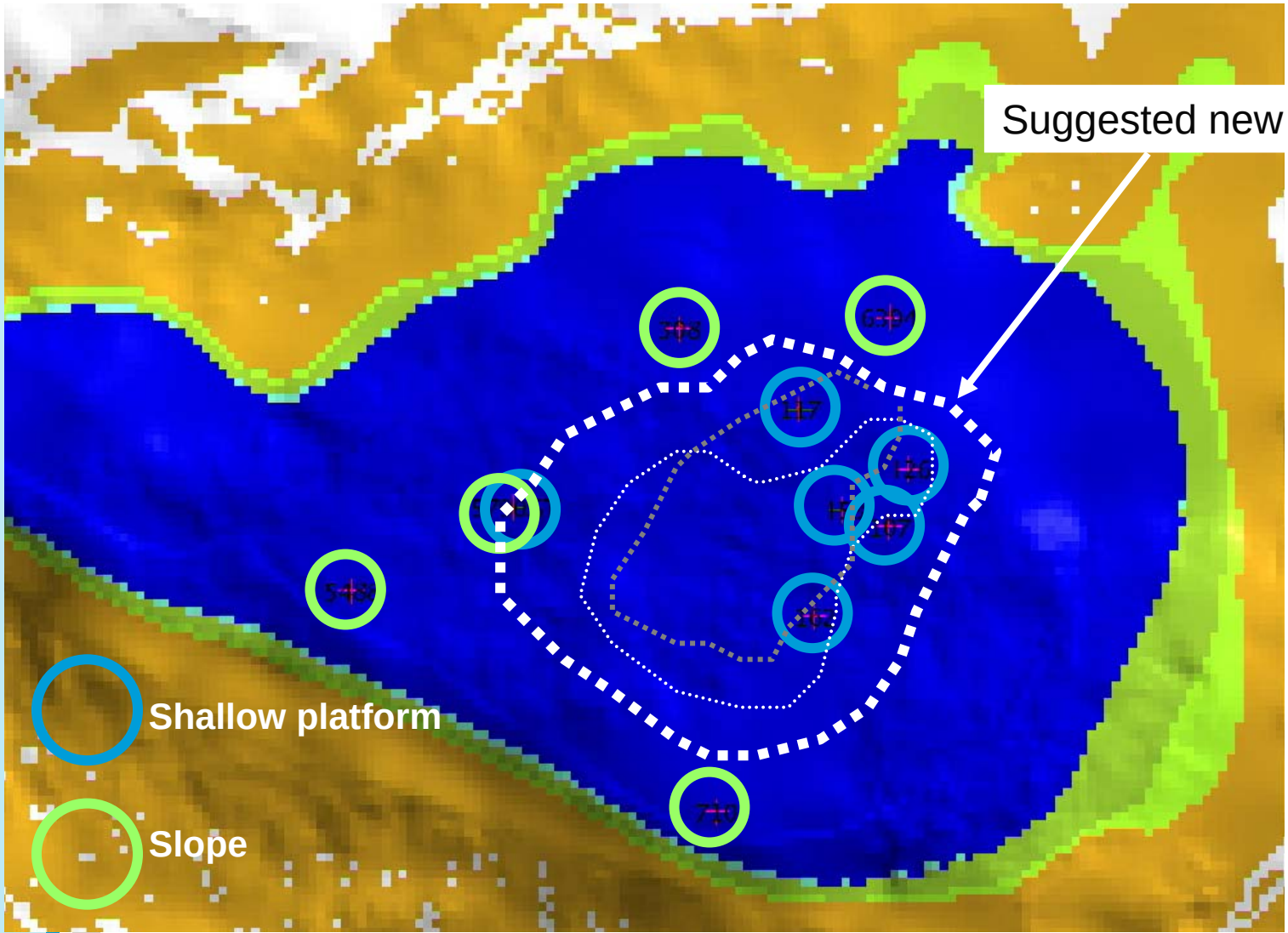
Platform – Slope Boundary



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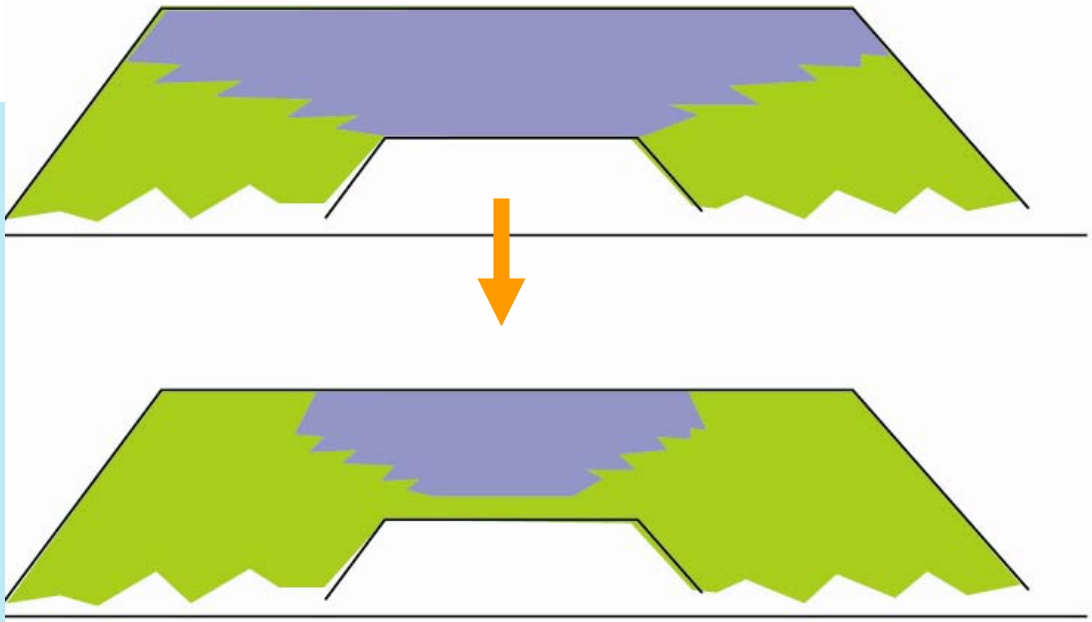
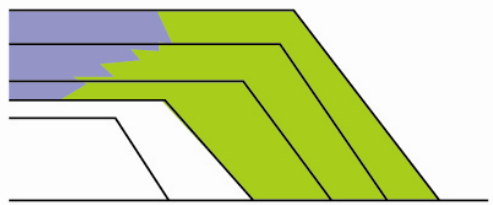
Revision of Conceptual Model



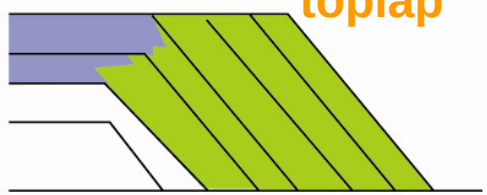
Alternative 1: grainstone / boundstone facies boundary on platform top. Possible in some circumstances.

aggradation



Alternative 2: grainstone / boundstone facies boundary on platform margin and extra platform progradation with toplap.

toplap



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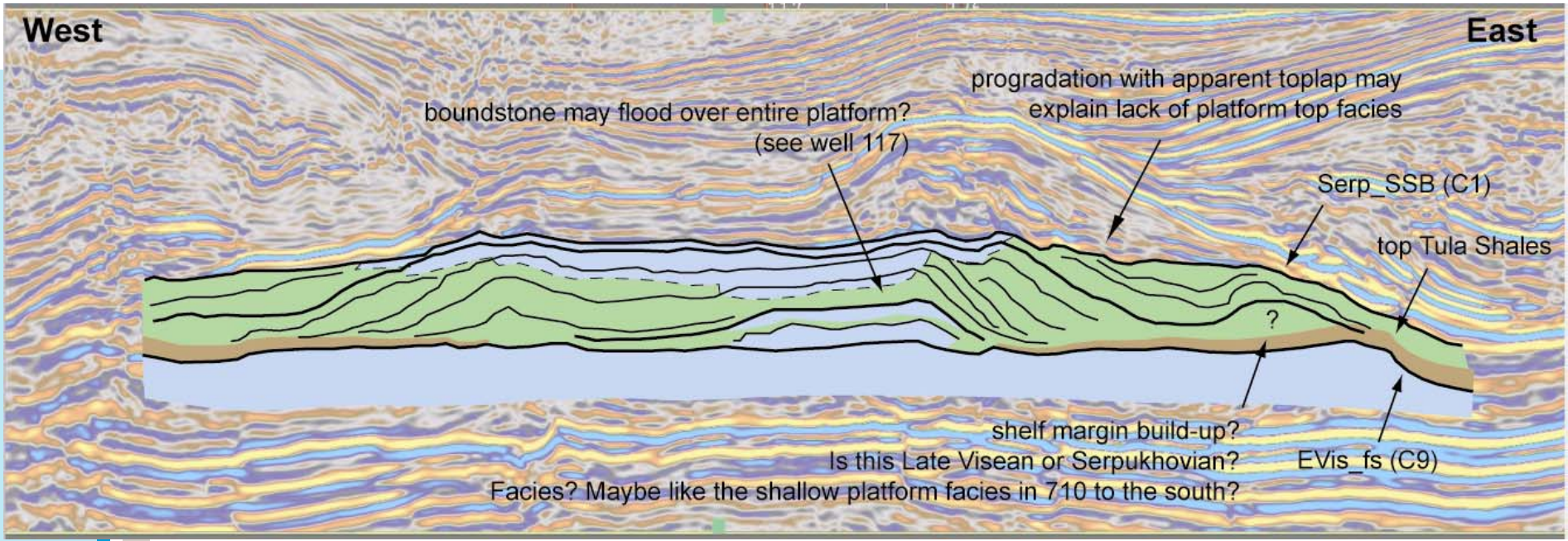
Revised Geological Model



- improved seismic resolution
- additional well data incorporated (including image logs)
- incorporated revised conceptual model

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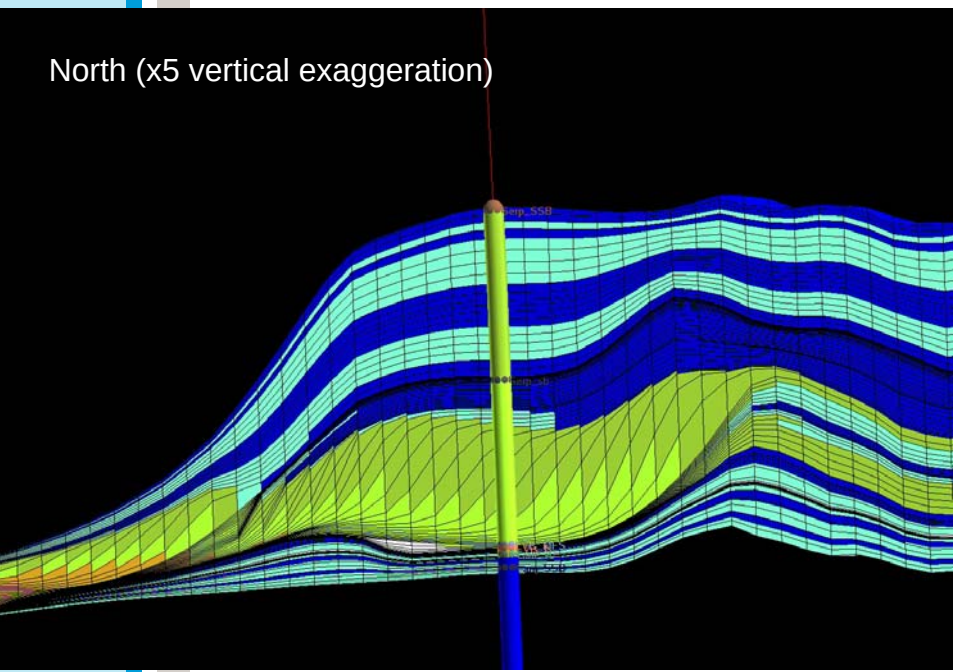
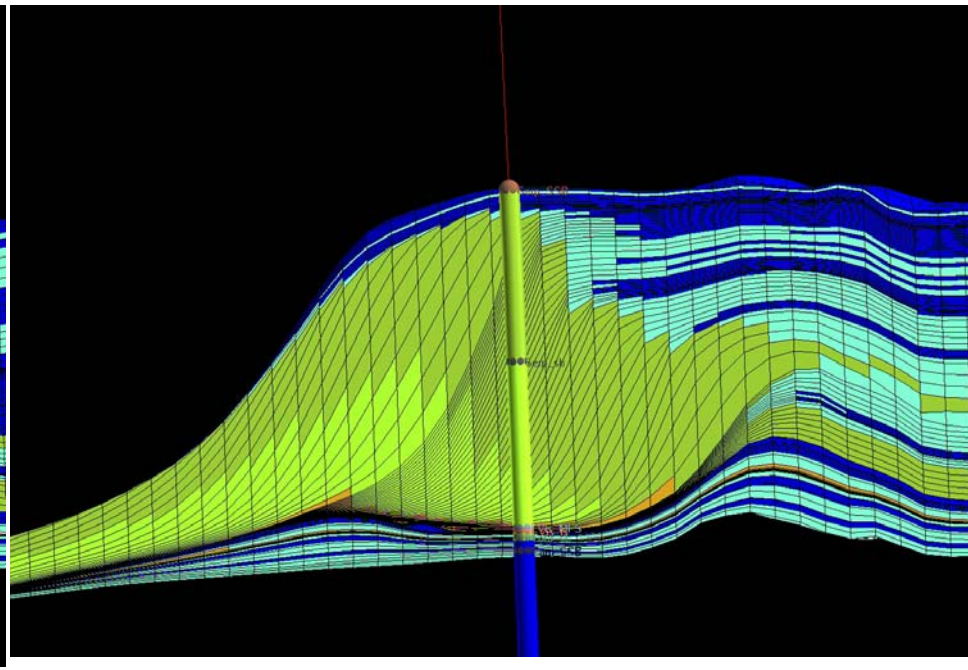
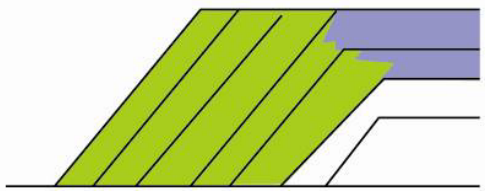
Model Improvements: Clinoform Morphology







- slope versus platform accretion

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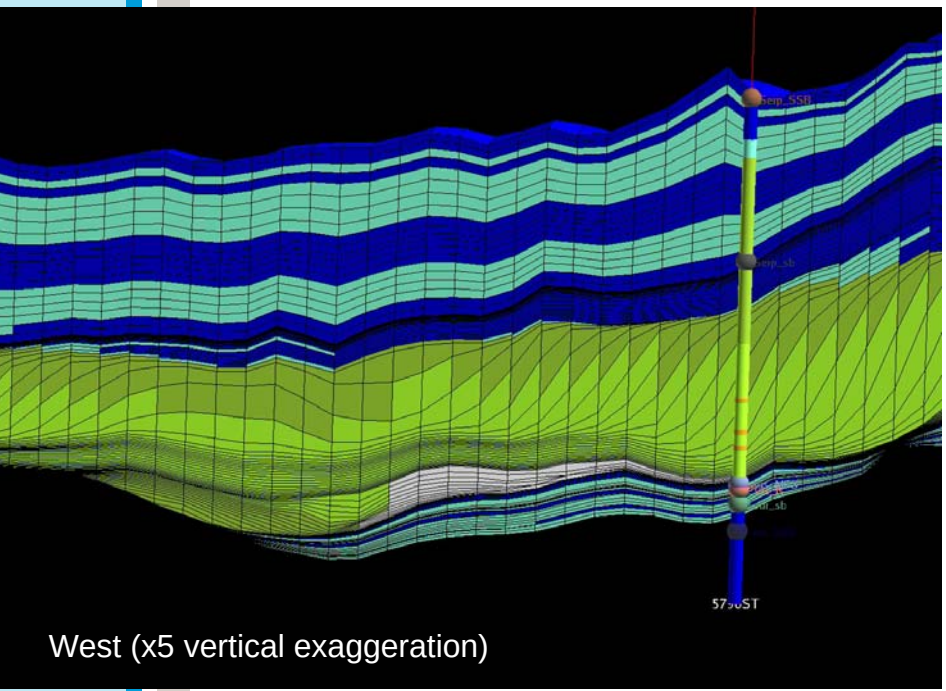
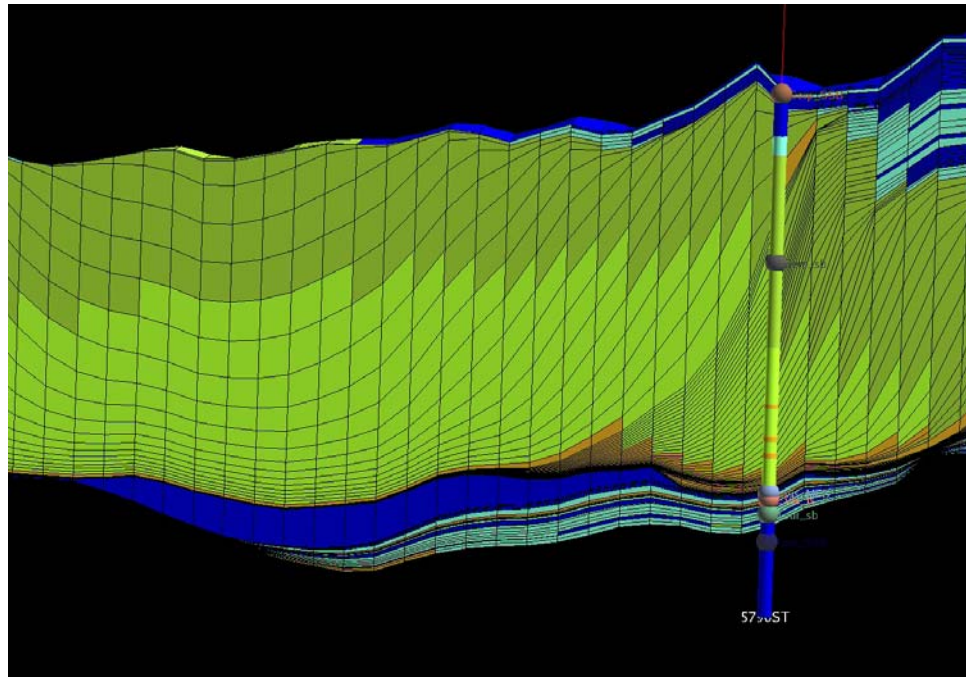
Model Improvements: Extent of Platform



West (x5 vertical exaggeration)



- variability in slope architecture

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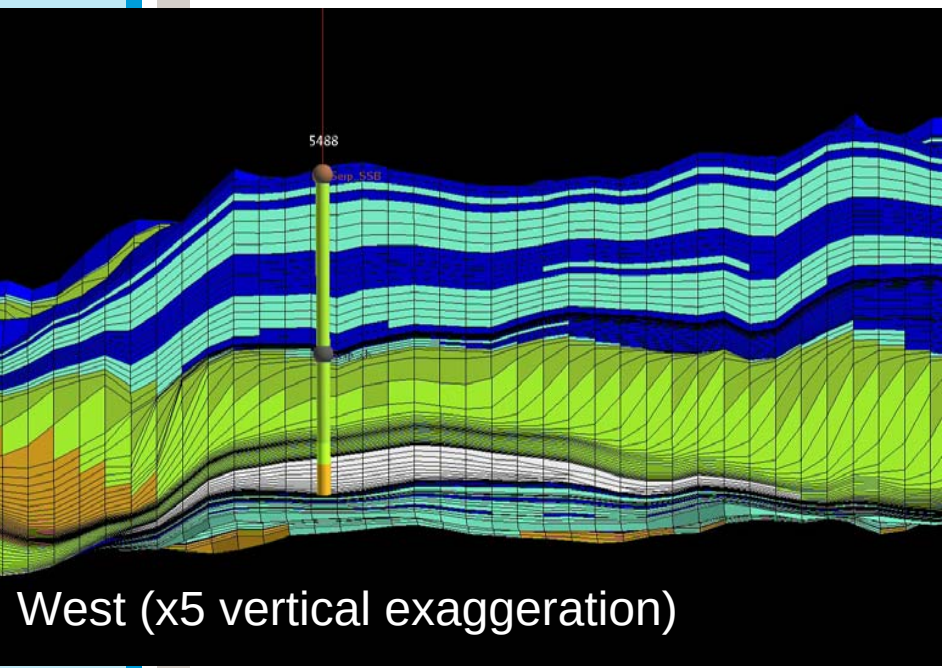
Model Improvements: Clinoform Architecture



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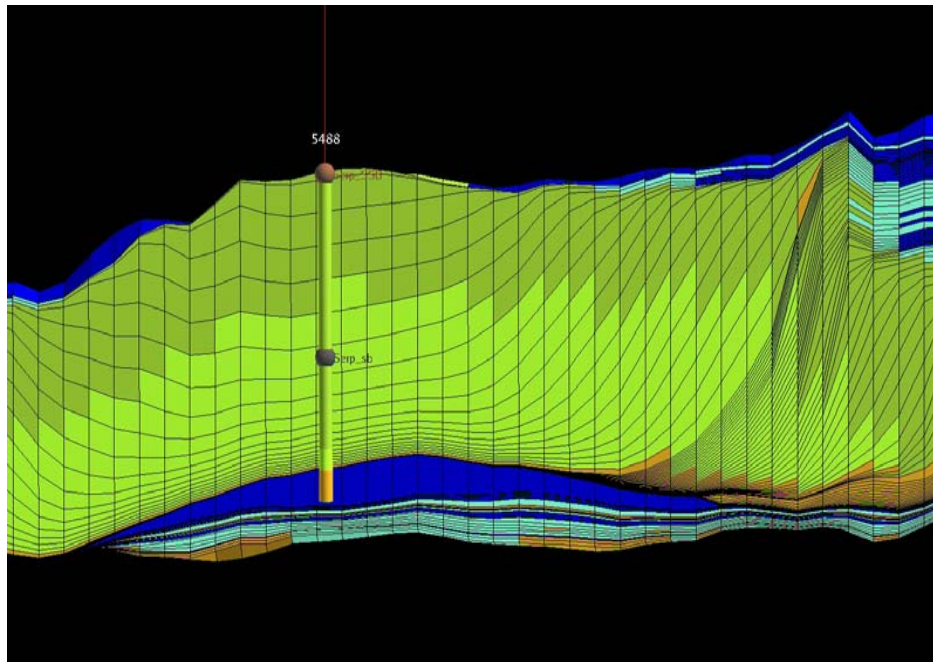

-model captures variable clinoform geometry and dips

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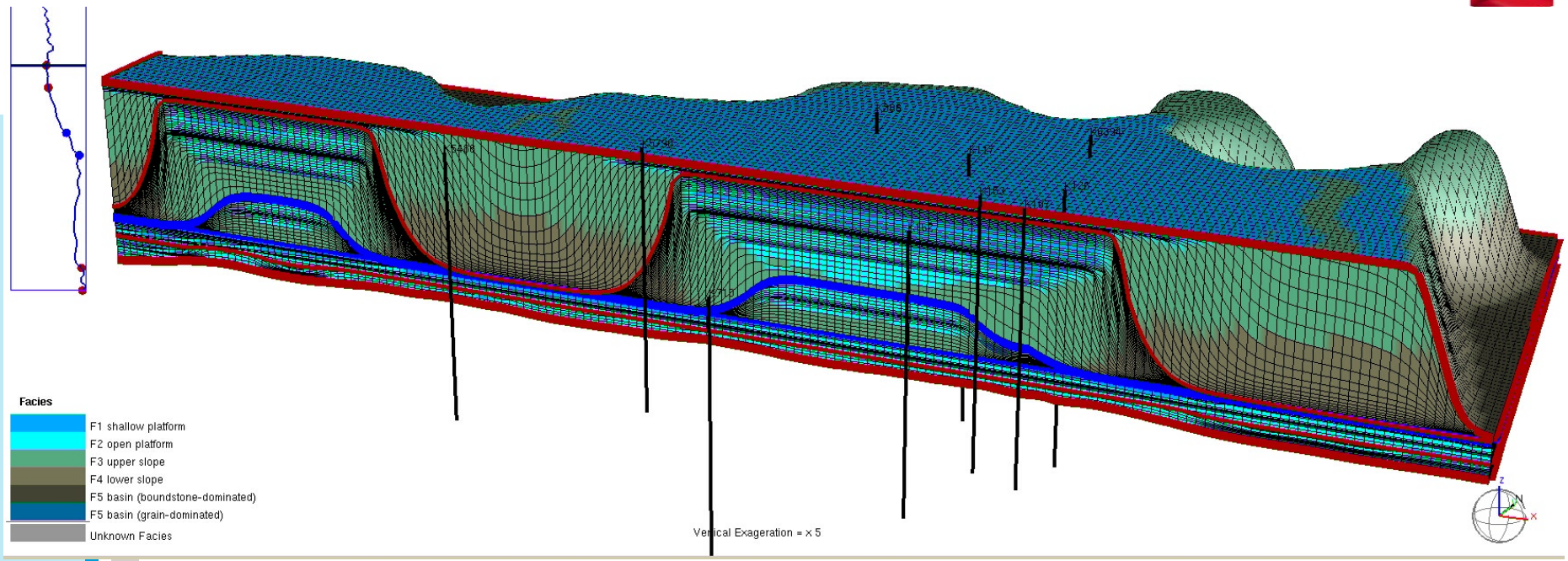
Isolated Carbonate Platform: Case Study



Key results:

- established workflow for 'conditioned' simulation
  - revised conceptual understanding of reservoir architecture
  - investigated extent of slope versus shallow platform facies
  - improved our understanding of clinoform characteristics
  - reservoir-quality / facies prediction in poorly imaged areas
- common visualization and communication tool

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