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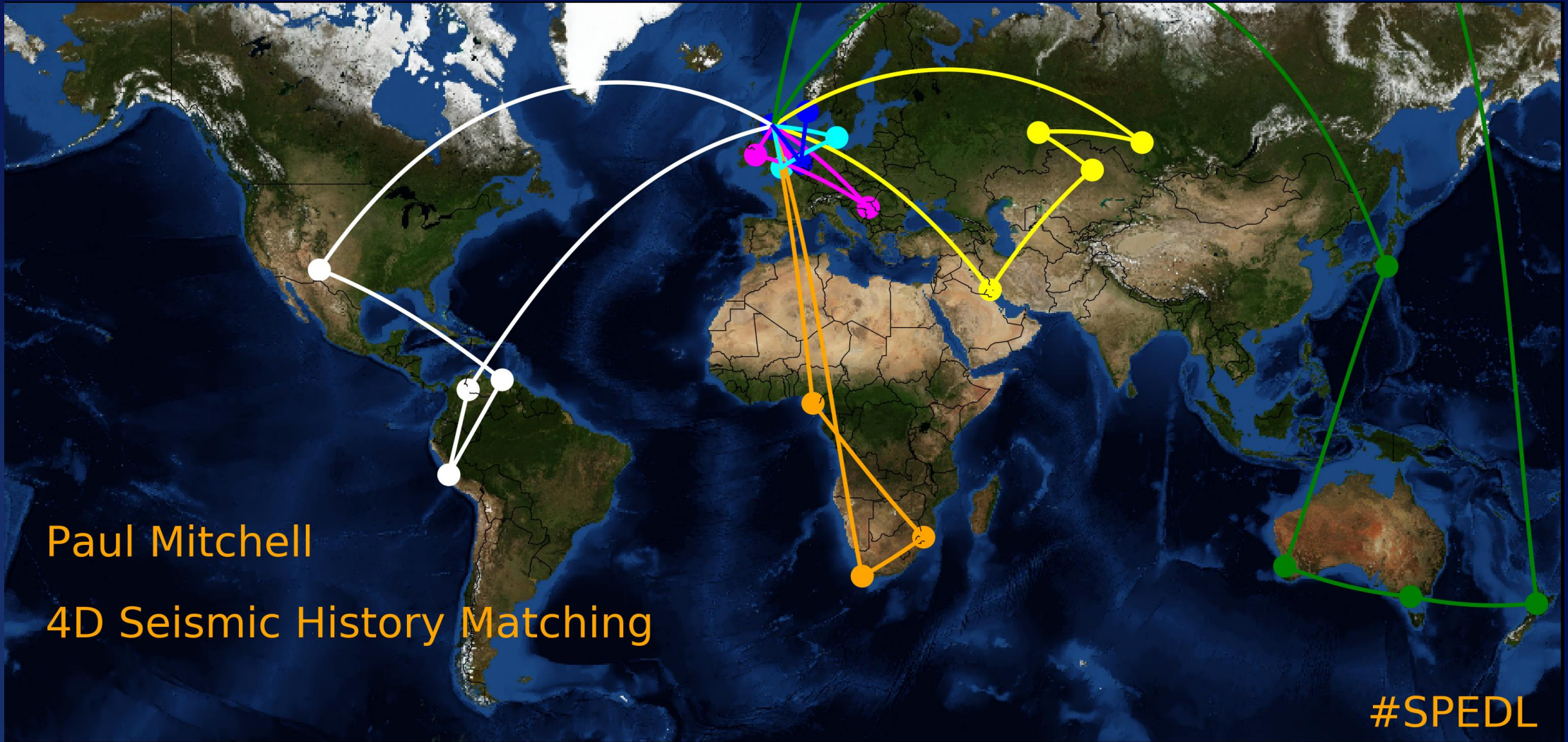
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4D Seismic History Matching

Paul Mitchell
TAQA



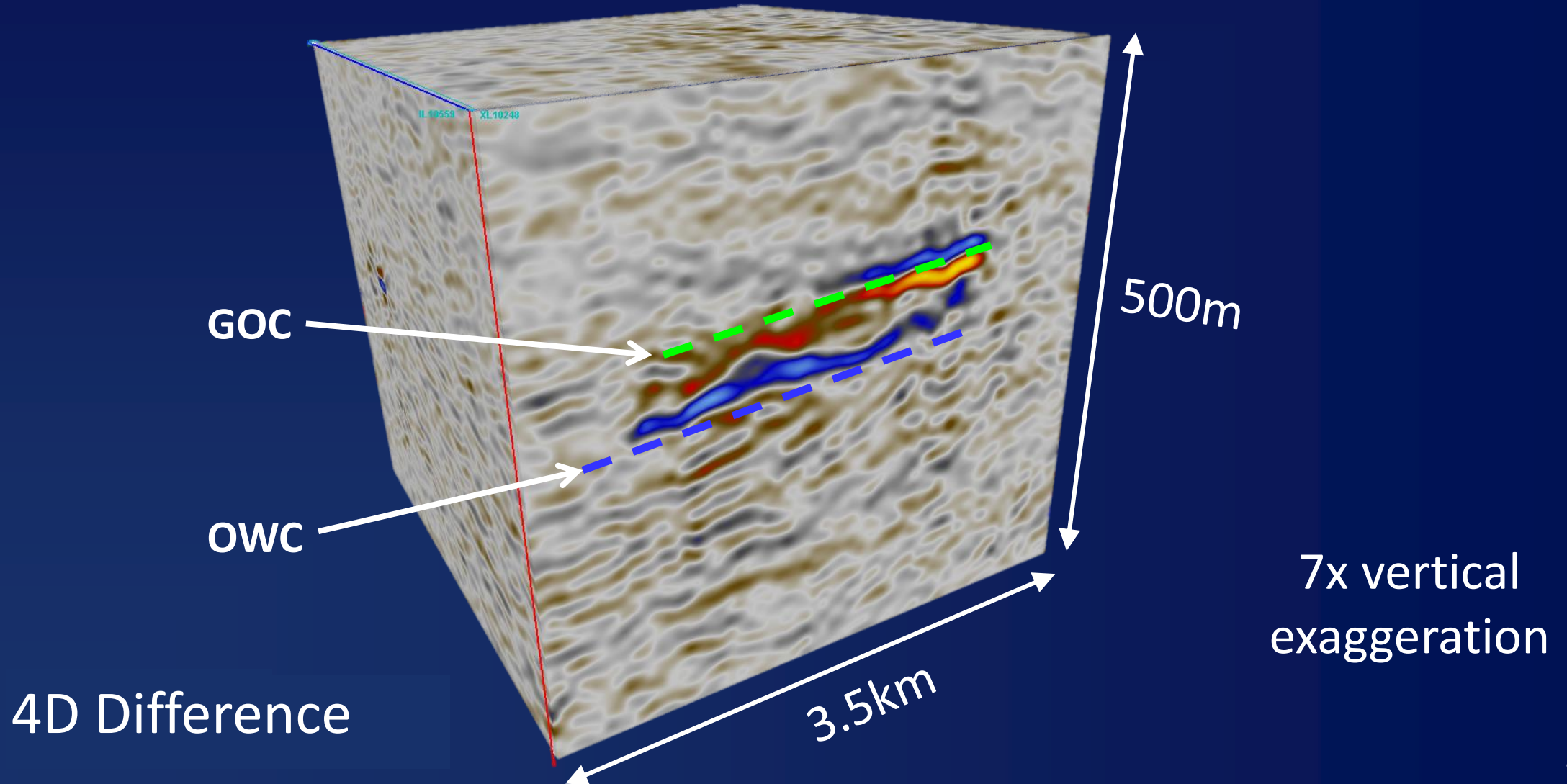
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Outline



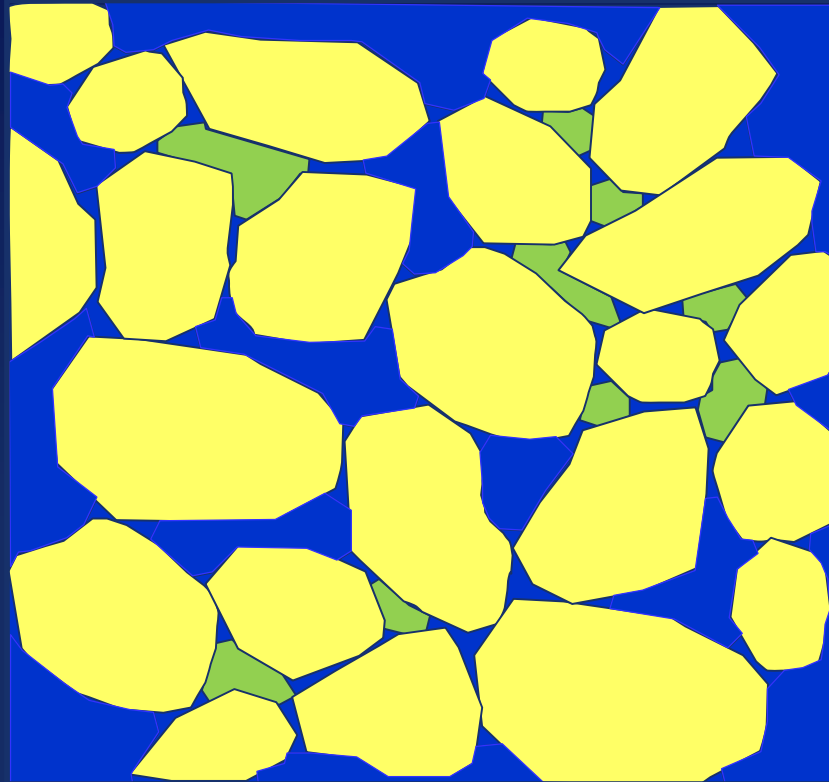
- Time-Lapse (4D) seismic
- 4D Seismic History Matching (4D SHM)
- The value of 4D SHM
- Harding & Gryphon case study
- 4D Assisted Seismic History Matching (4D ASHM)
- Future directions
- Conclusions

Introduction to Time-Lapse or 4D Seismic



How Does 4D Work? Water Sweep...

Velocity ↑
Density ↑

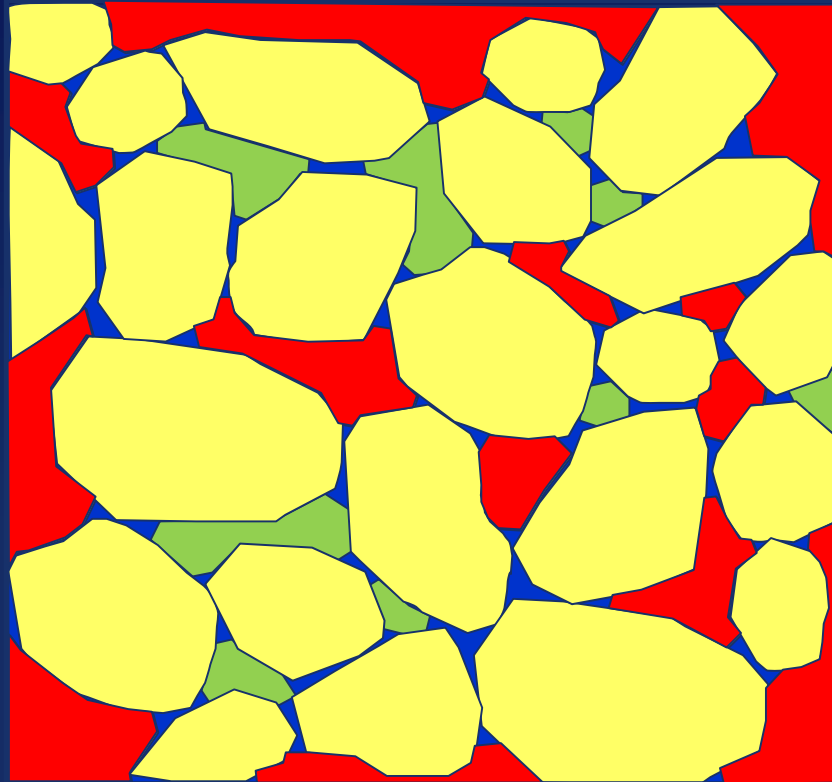



0 1mm



How Does 4D Work? Gas Sweep...

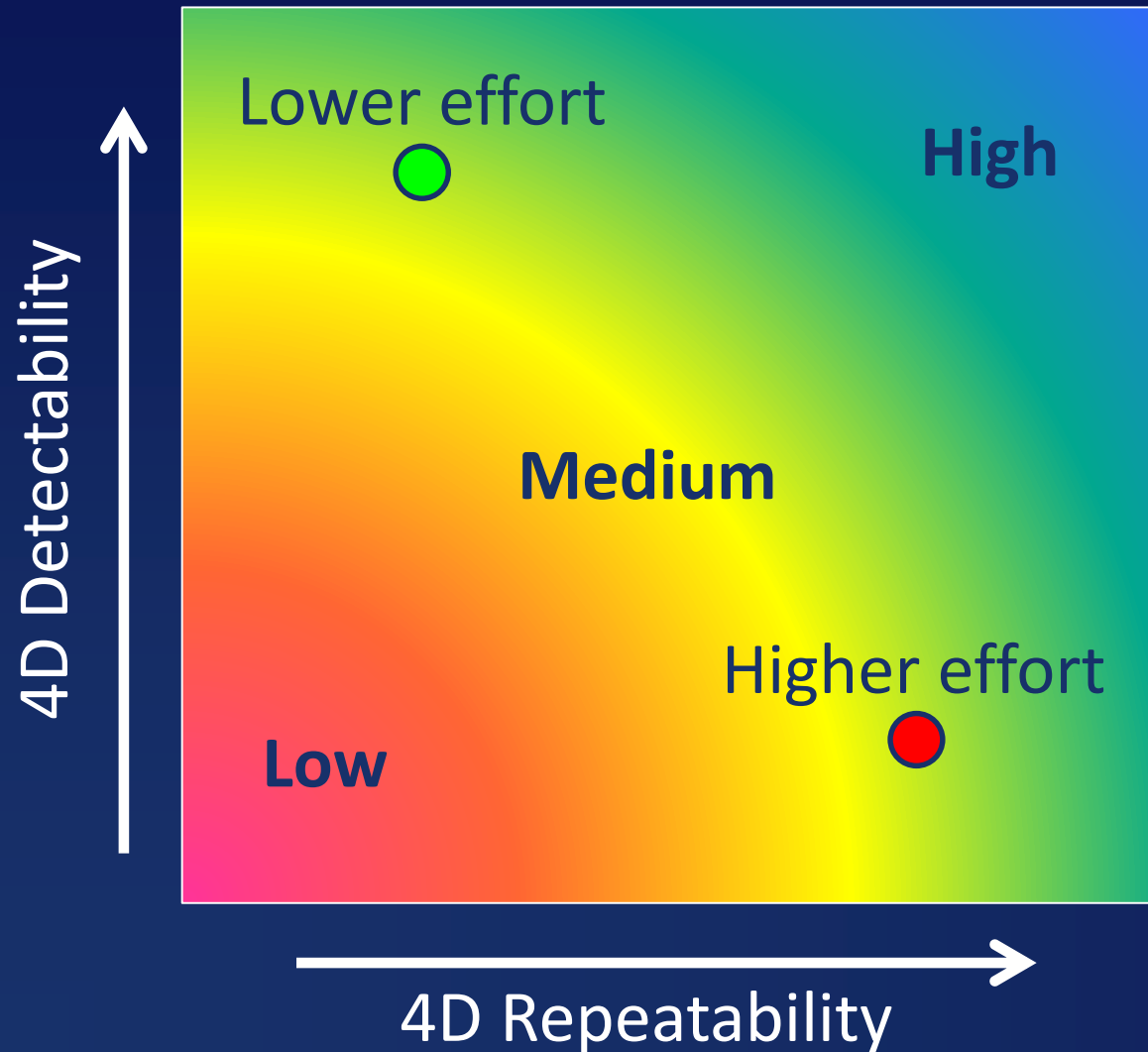
Velocity Density



0 1mm



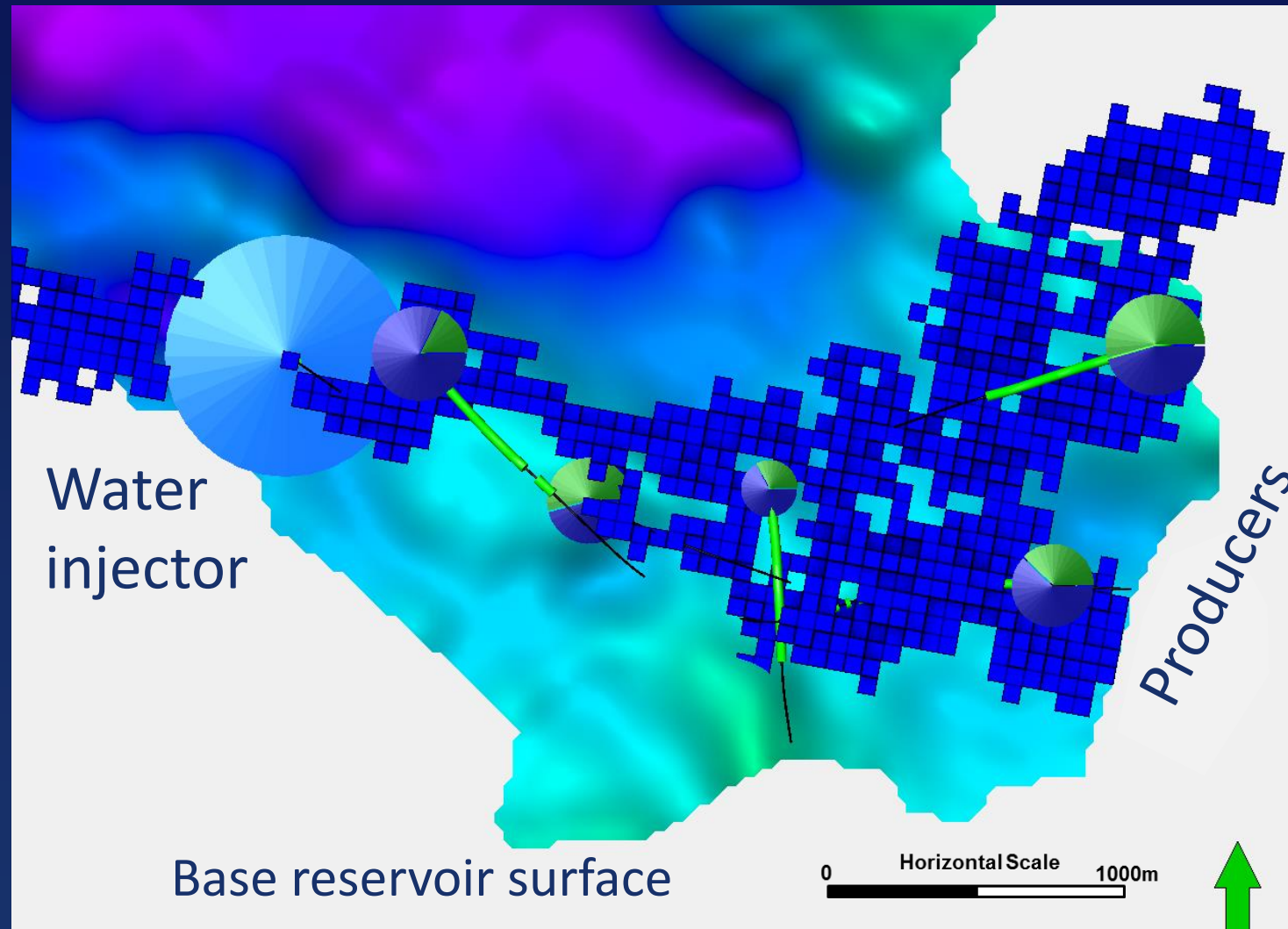
4D Chance of Success



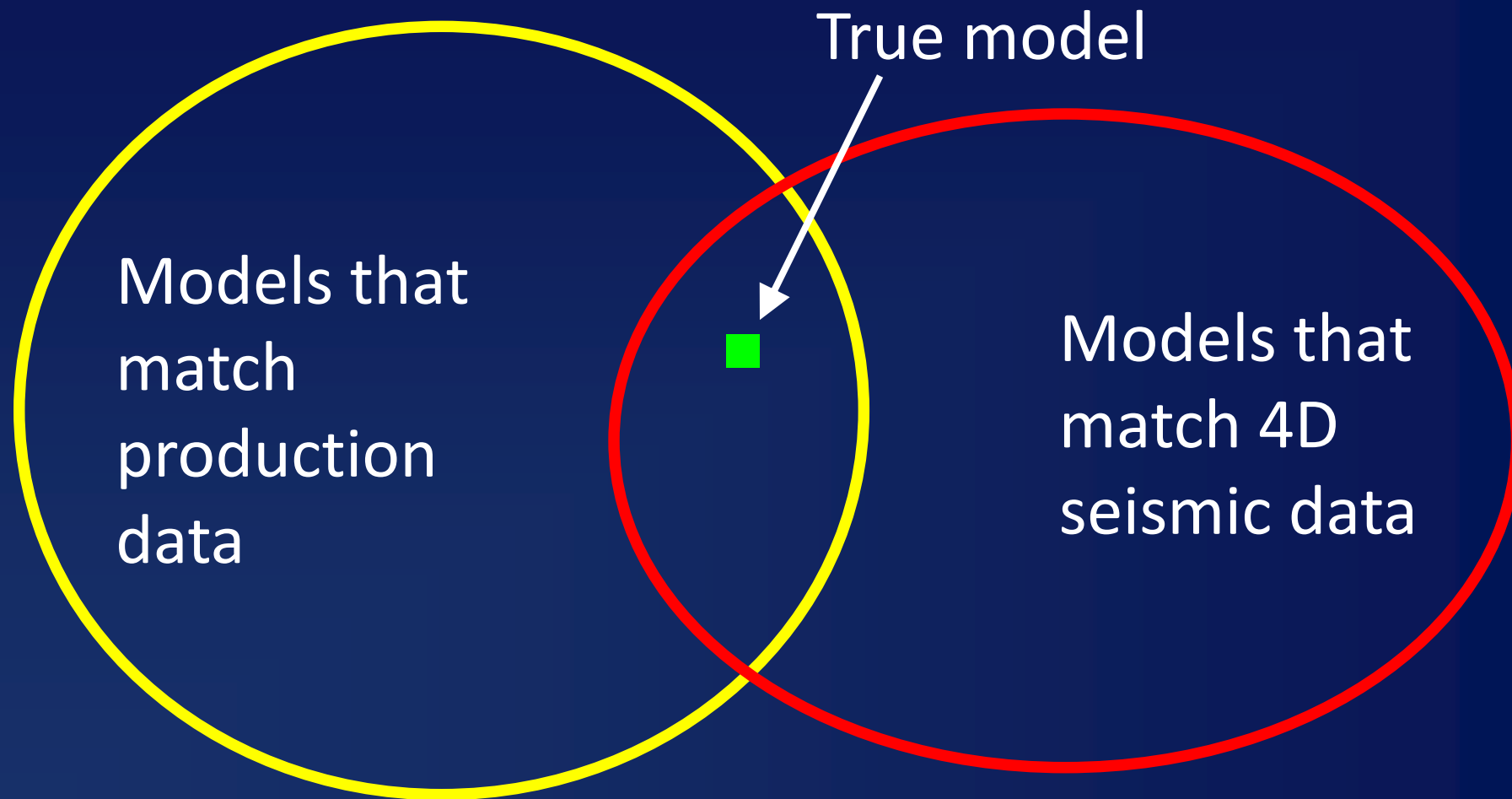
- 4D Detectability
 - Rock & fluid properties
 - Depletion process
 - Resolution
- 4D Repeatability
 - Acquisition geometry
 - Processing
 - Overburden complexity
 - Signal-to-noise

Reservoir Monitoring with 4D Seismic

- Production data
 - temporally dense
 - spatially sparse
- 4D seismic data
 - spatially extensive
 - temporally sparse
- Complementary

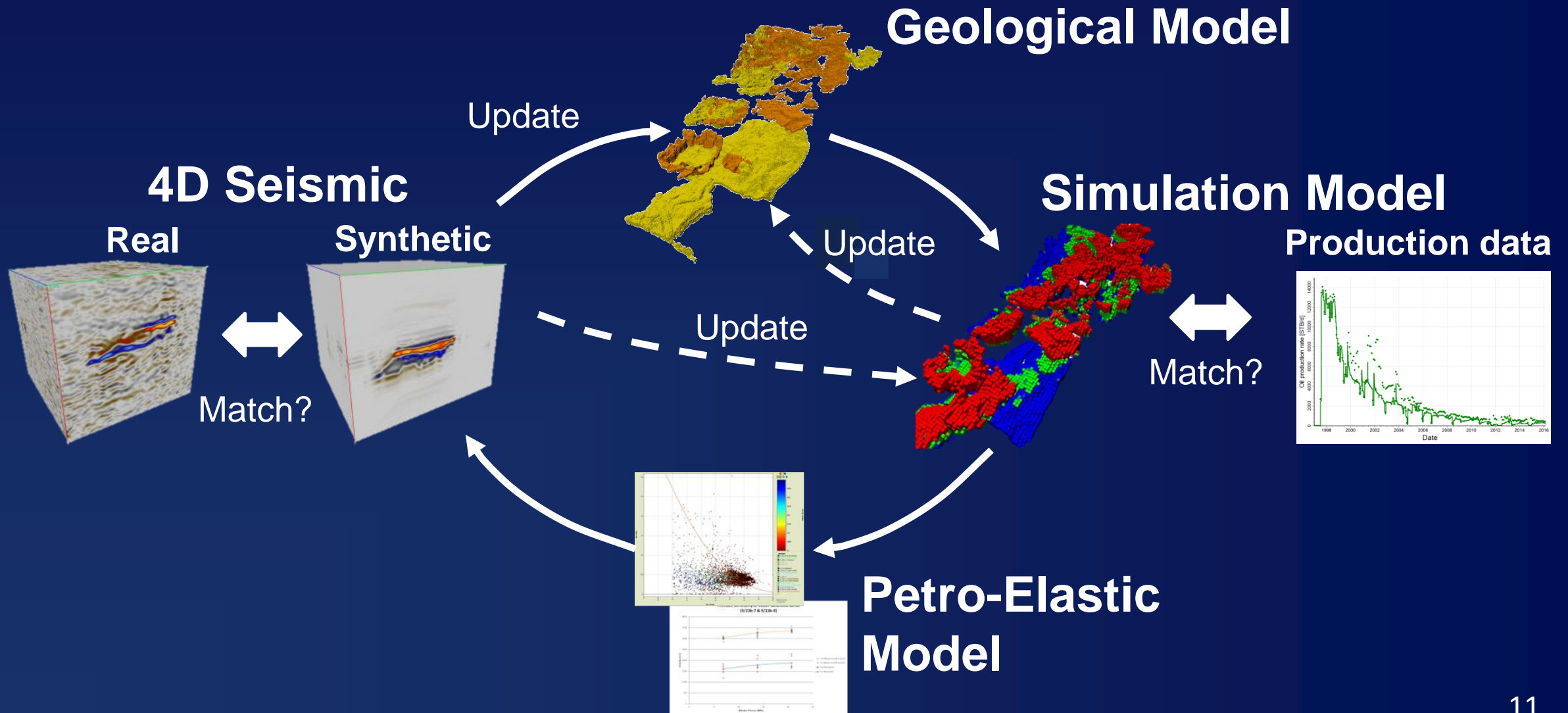


Principle of 4D Seismic History Matching



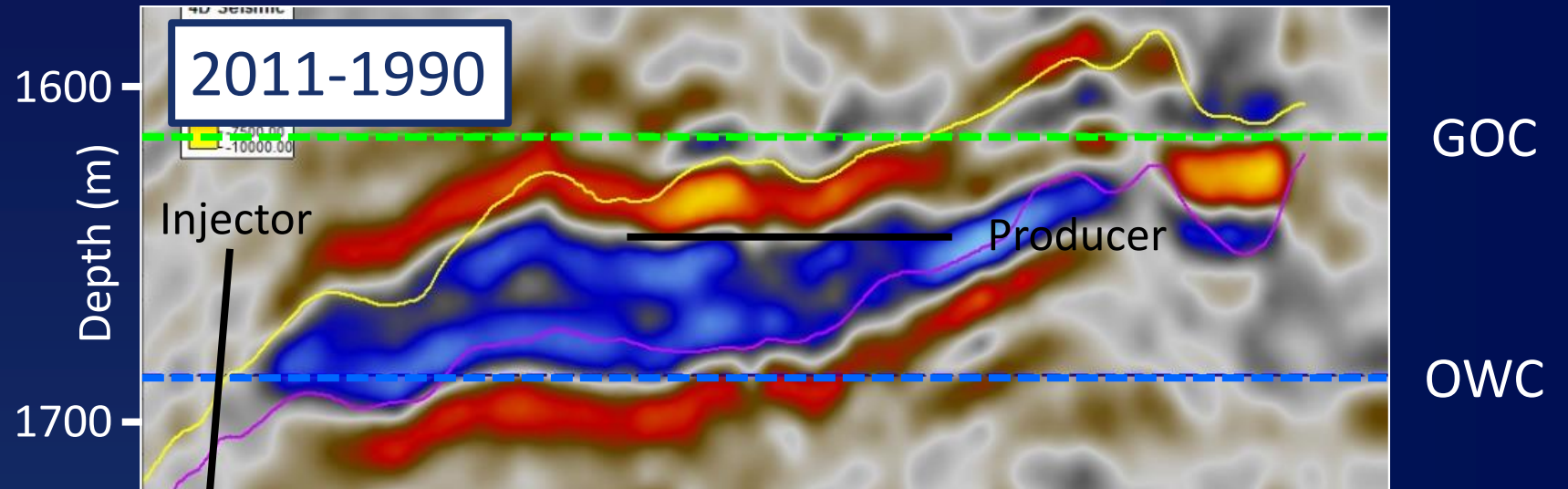
4D seismic history matching using information from the flooded zone, Jin, L., et al., 2012.

4D Seismic History Matching Workflow

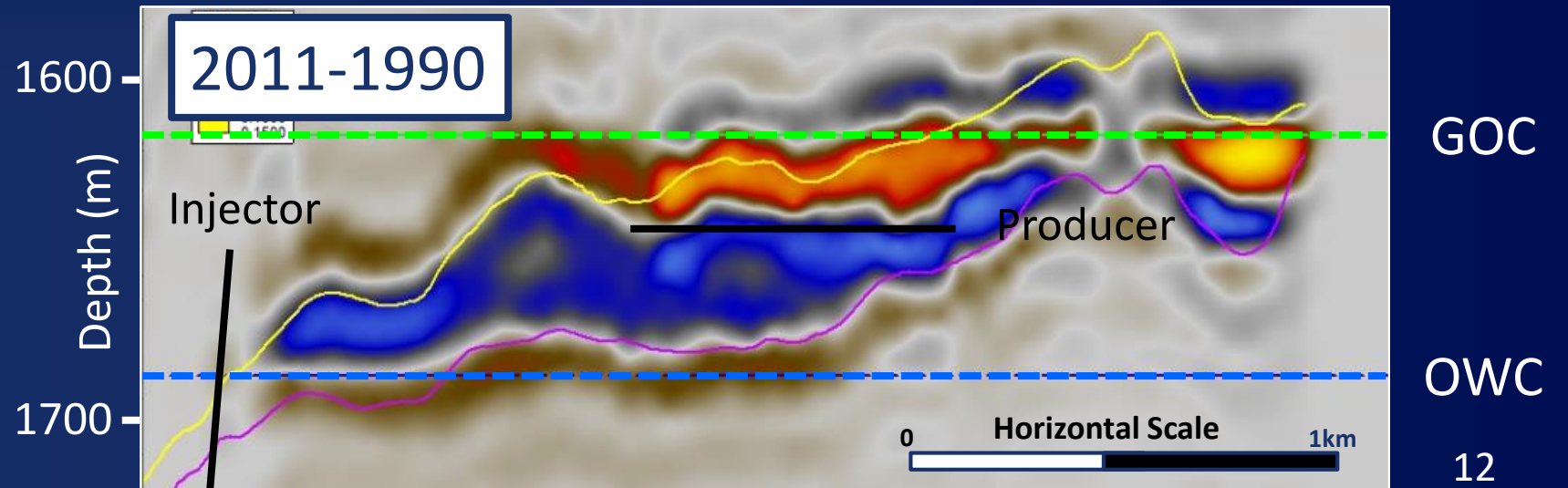


Seismic History Matching Example

Real 4D Seismic

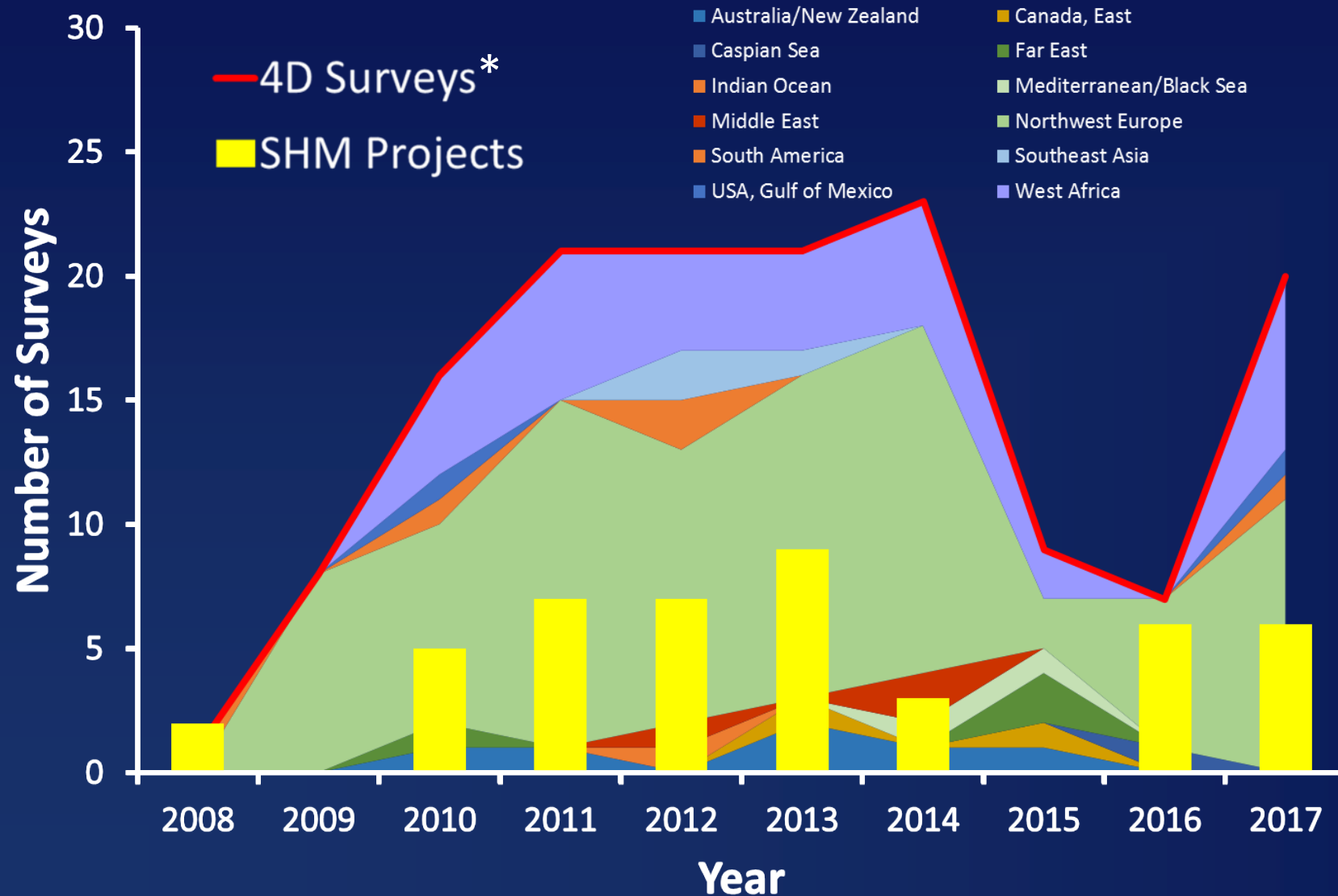


Synthetic 4D
Seismic



Acoustic Impedance
← →
Decrease Increase

The Value of 4D SHM

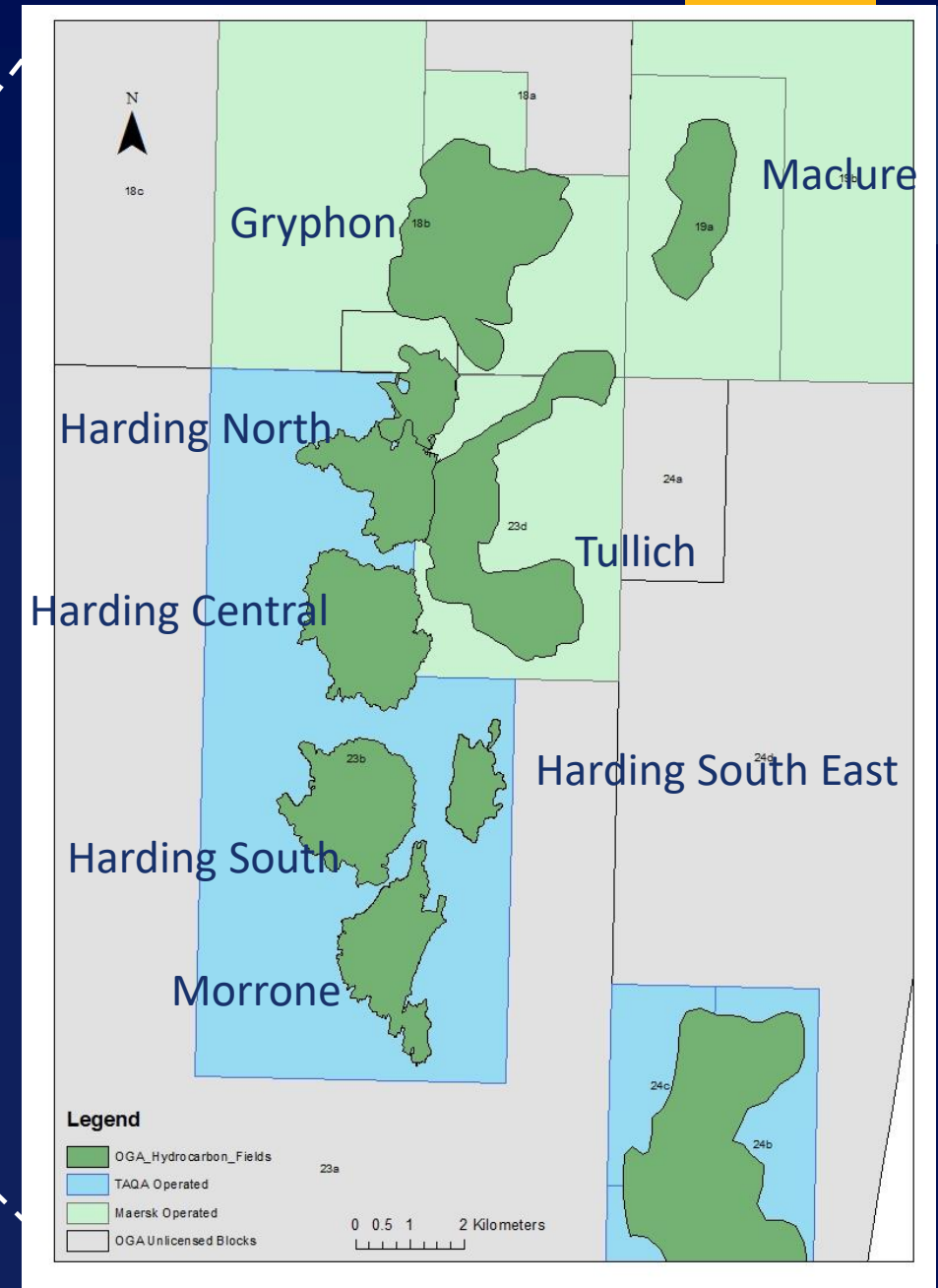


- \$1-2bn annual spend on 4D seismic globally
- Greater value can be extracted from the data

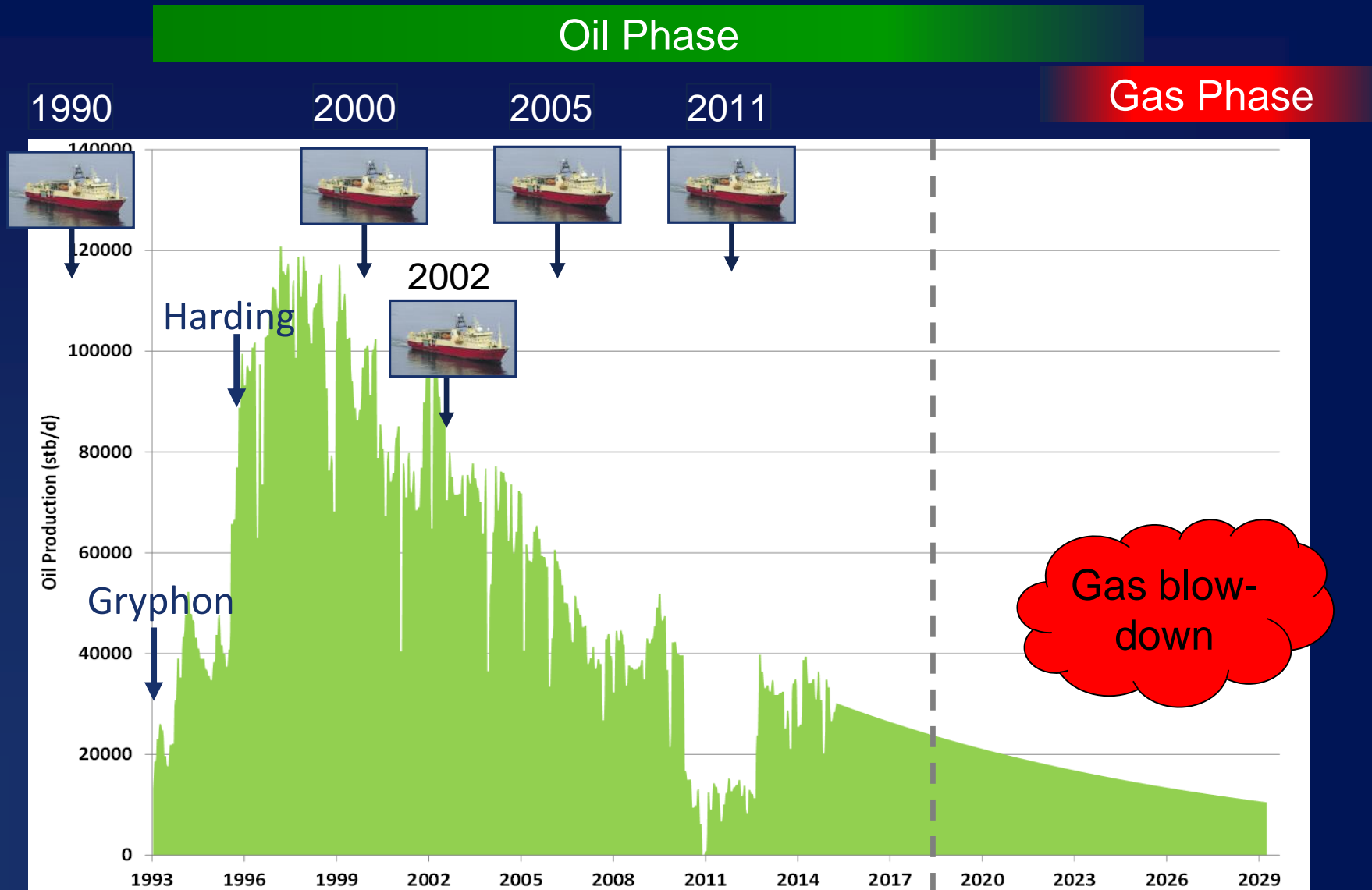
* Source: SeismicBase by IHS Markit

Harding & Gryphon Fields

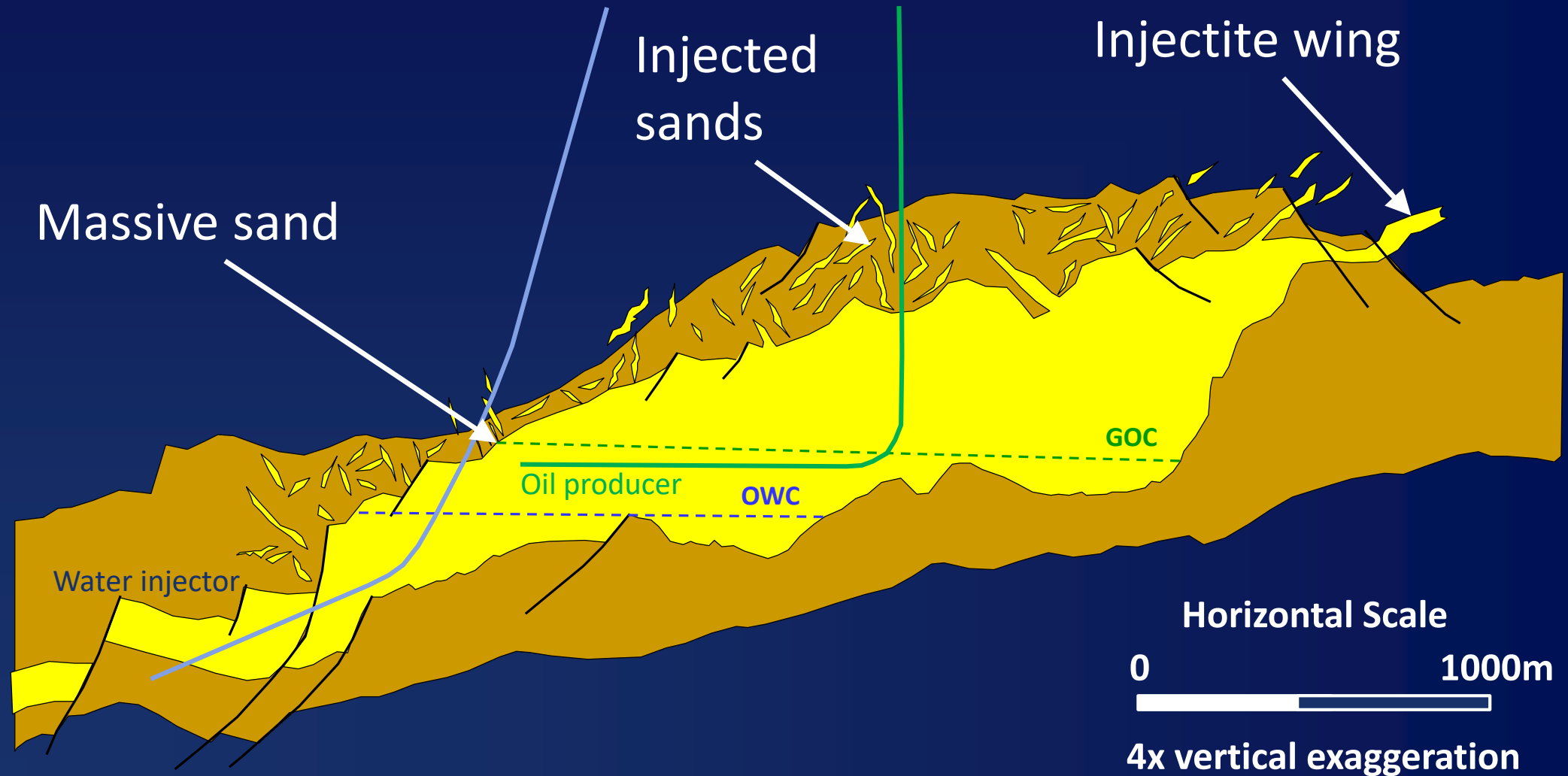
- North Sea
 - 320km NE Aberdeen
- TAQA and Total operated fields
- Oil production
 - Gas caps remain
- Morrone undeveloped



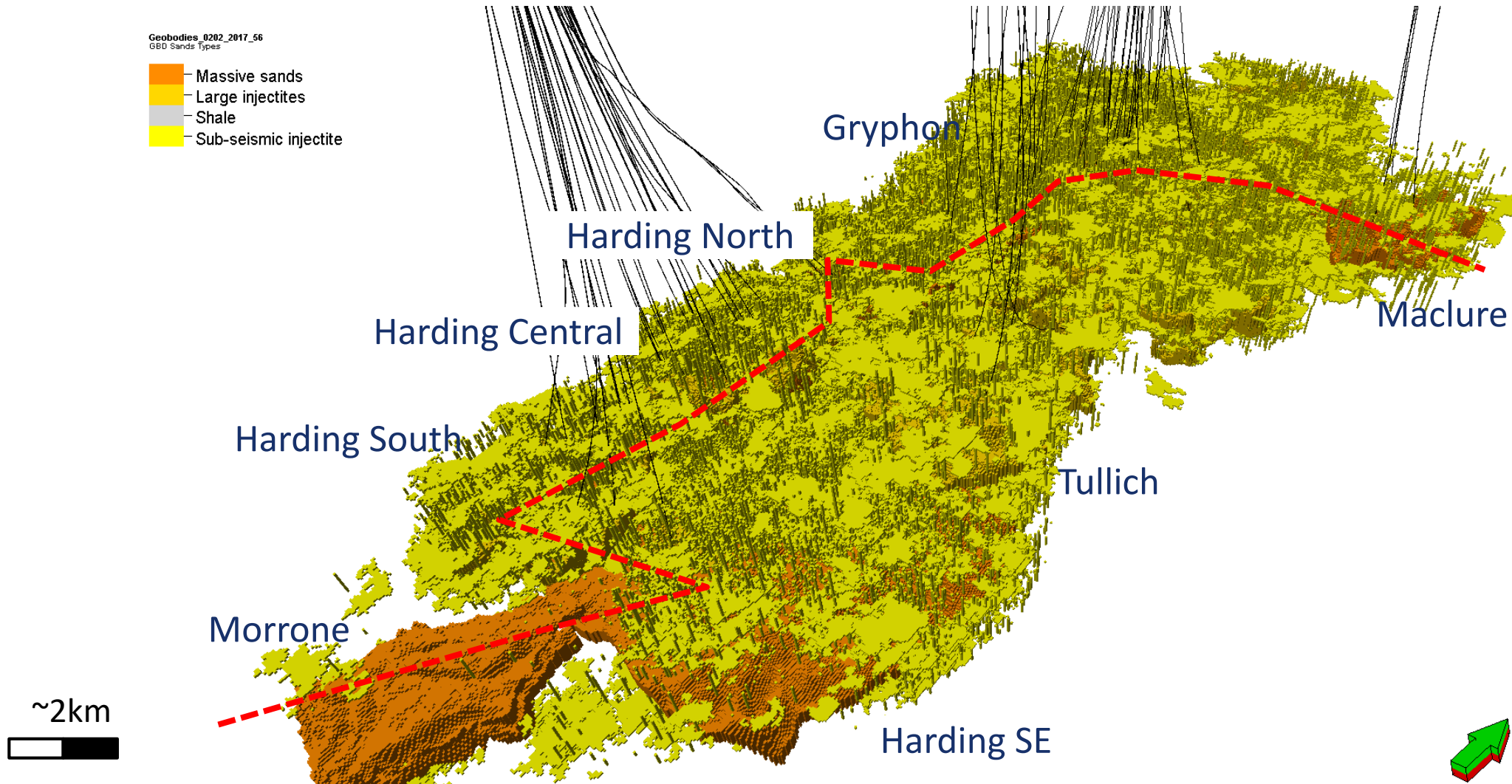
Production & Seismic History



Geology

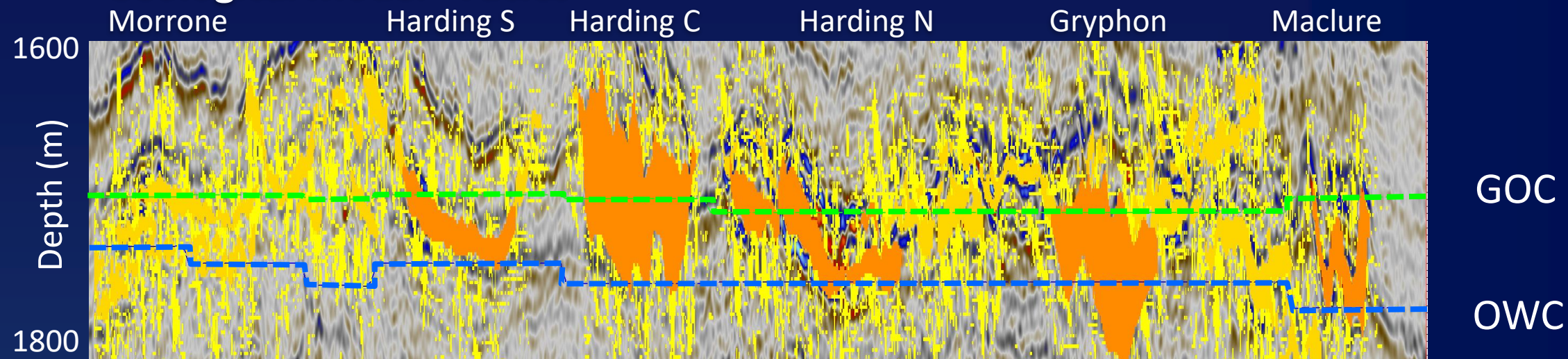


Geological and Simulation Models

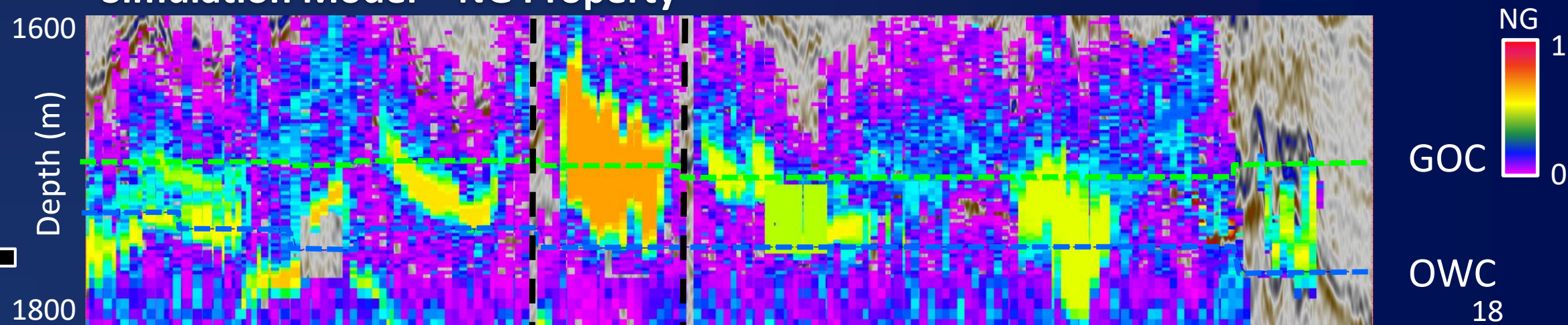


Initial Models

Geological Model - Facies

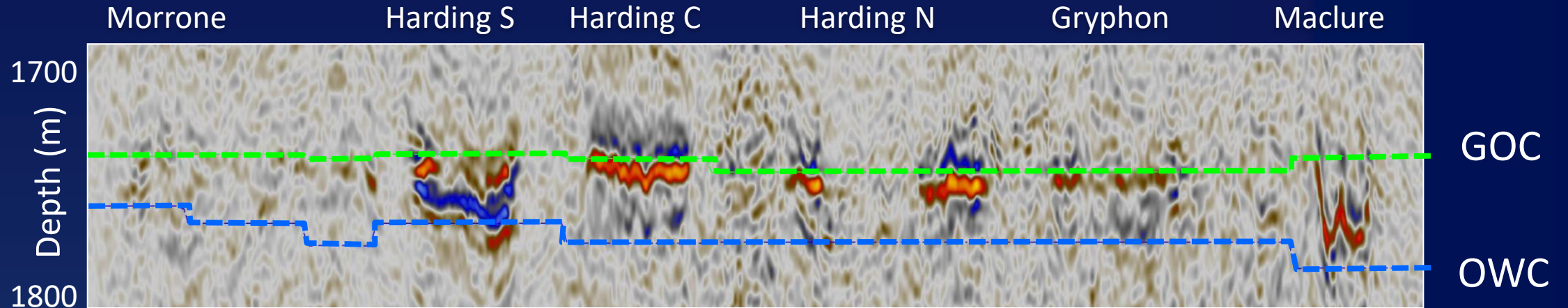


Simulation Model – NG Property

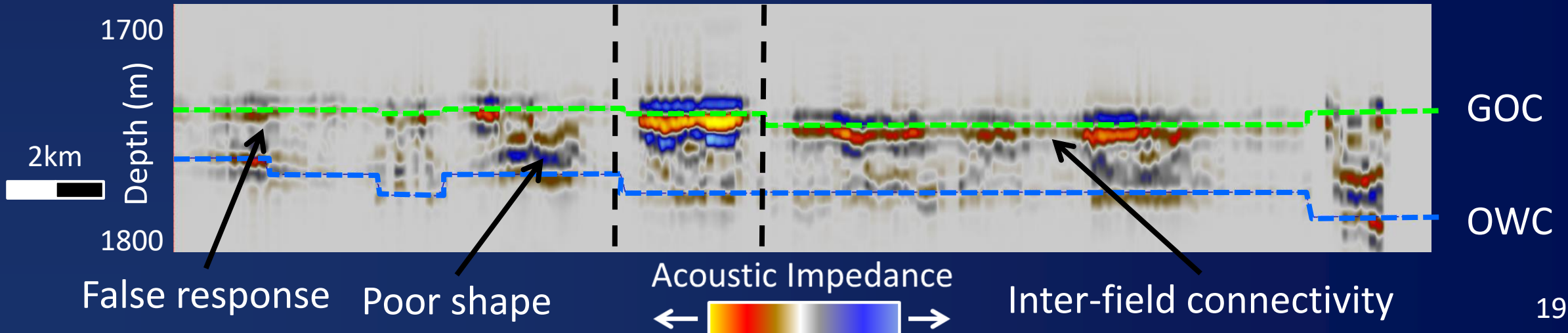


Initial Model 4D Seismic

Real 4D Seismic Difference



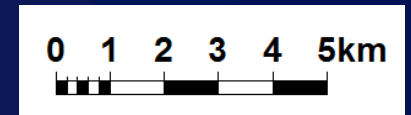
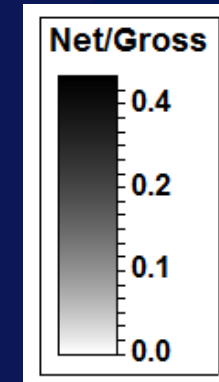
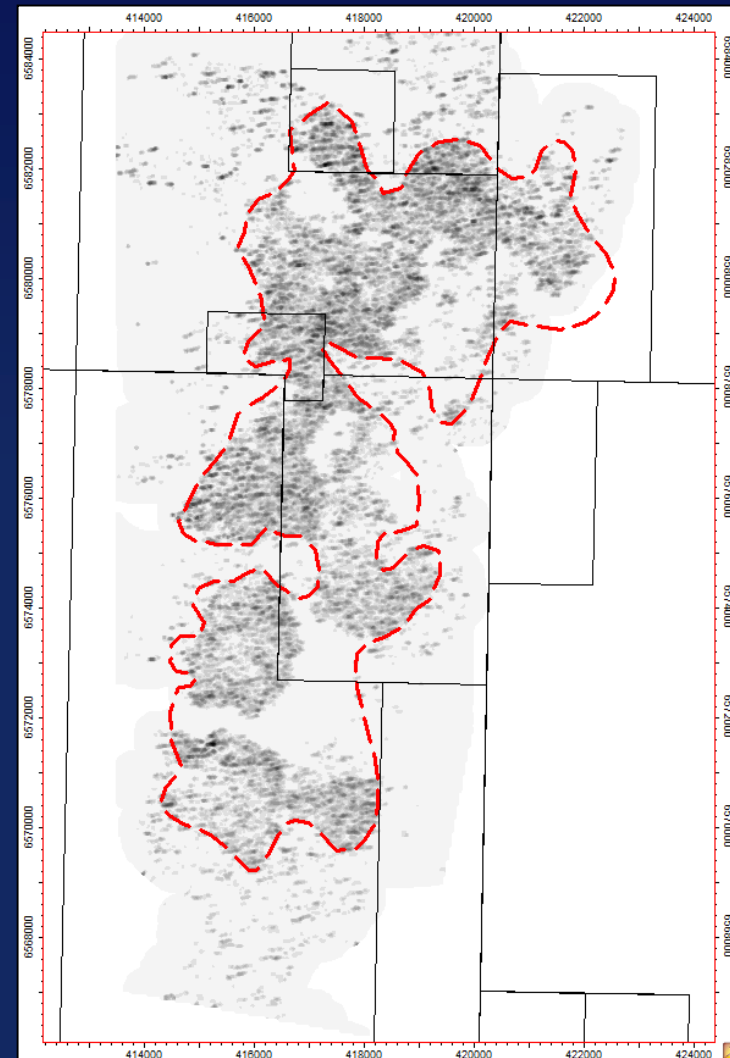
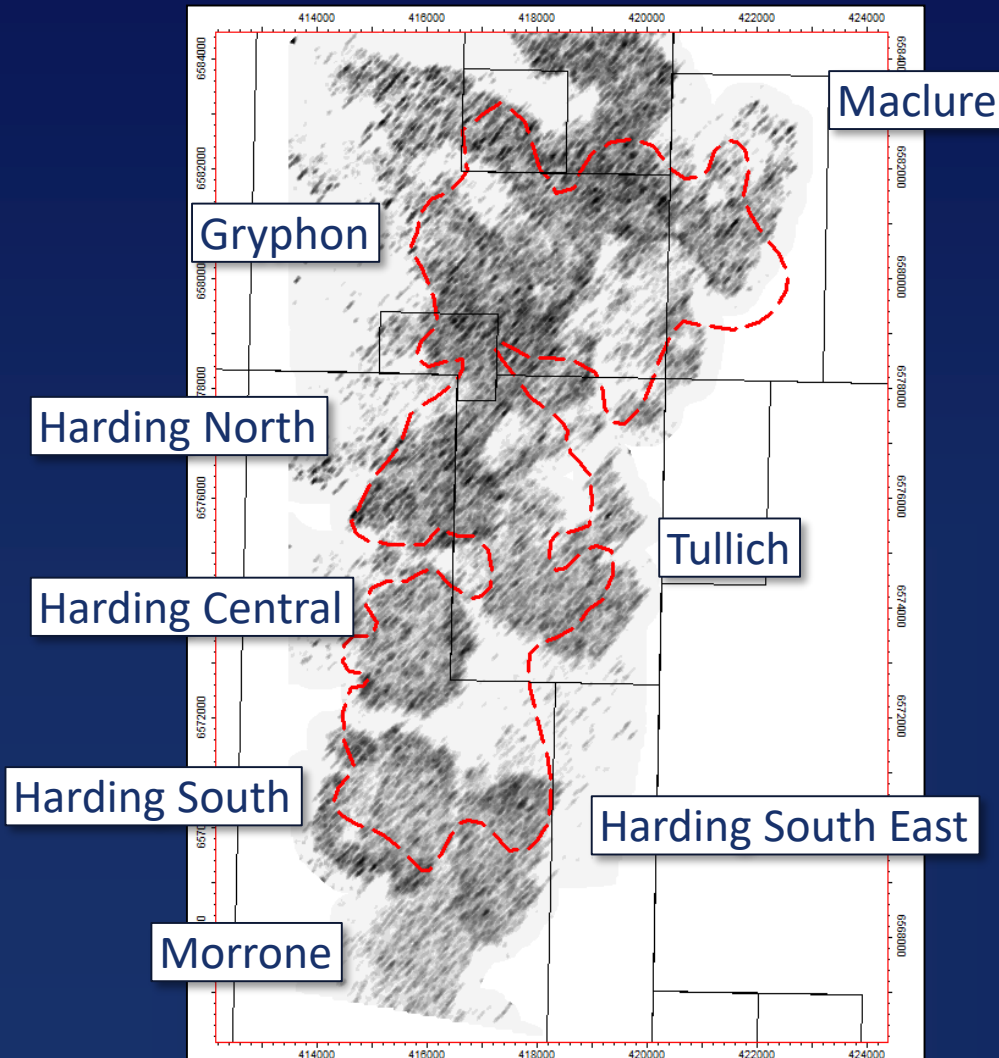
Model 4D Seismic Difference



Redistribution of Sand Injectites

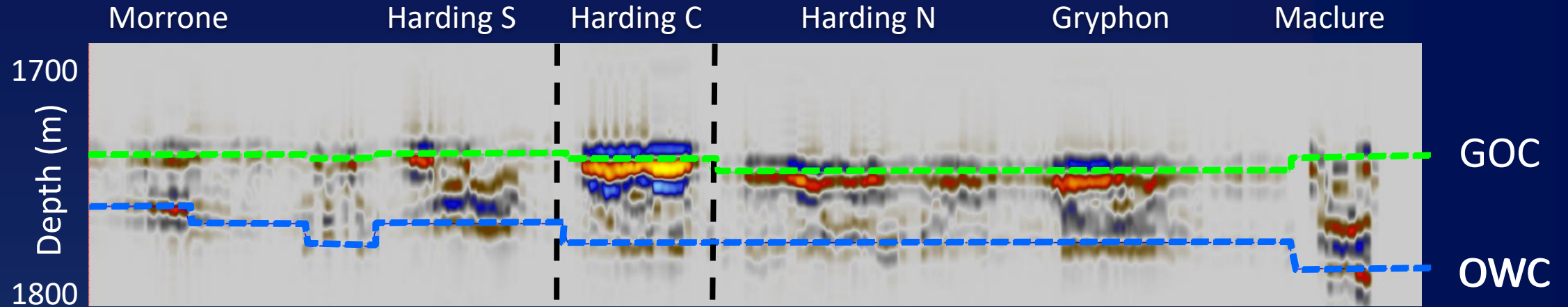
Initial Injectite Density

Updated Injectite Density

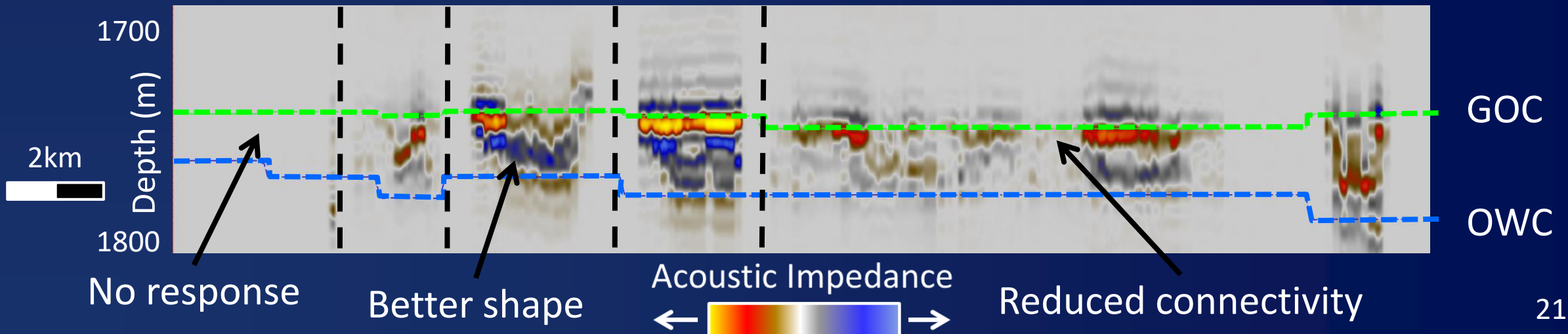


Updated Model 4D Seismic

Initial Model 4D Seismic Difference

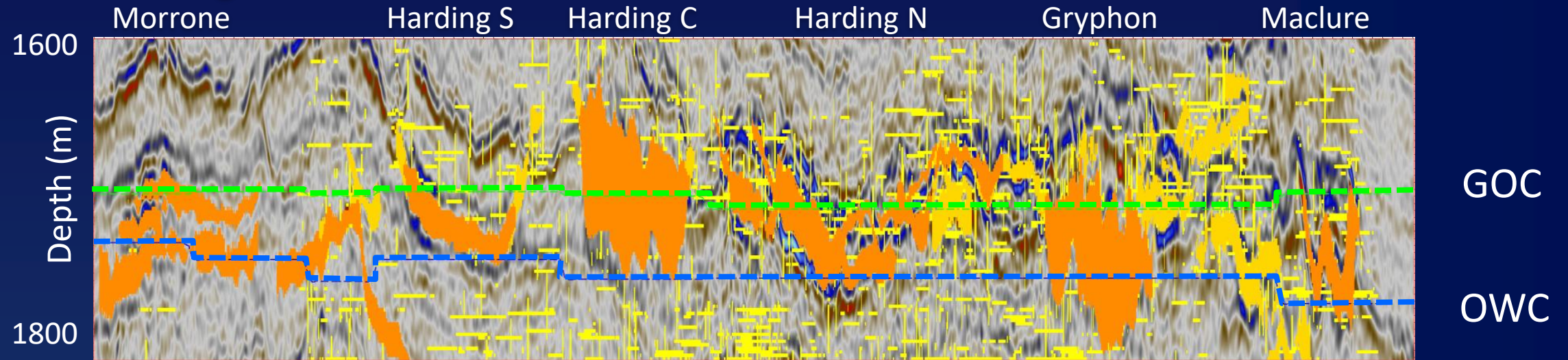


Updated Model 4D Seismic Difference

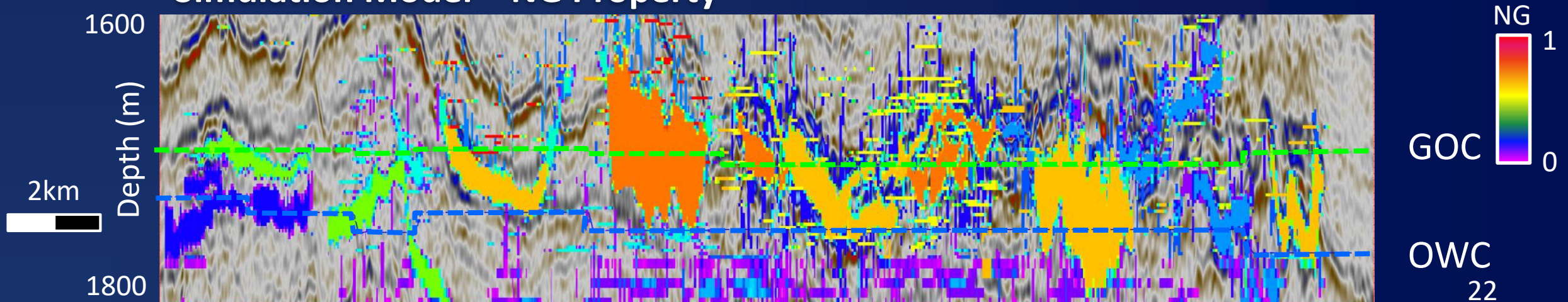


Fine-Scale Models

Geological Model - Facies

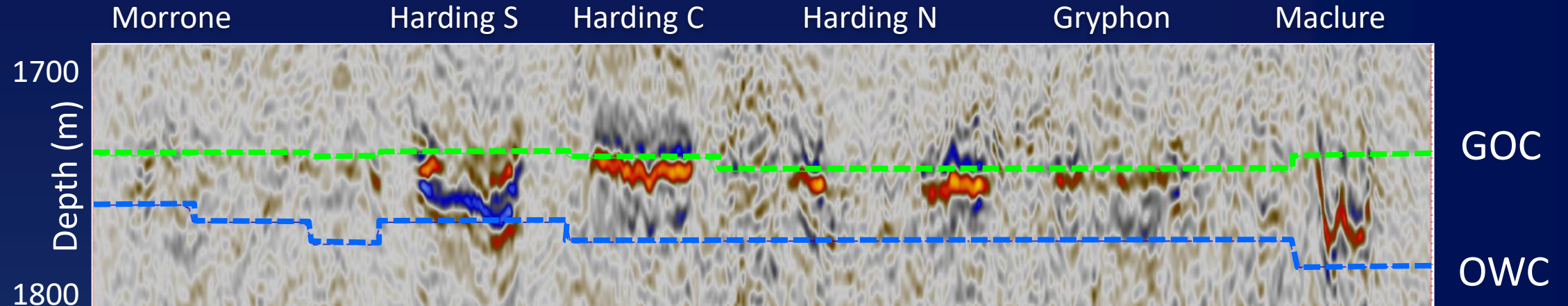


Simulation Model – NG Property

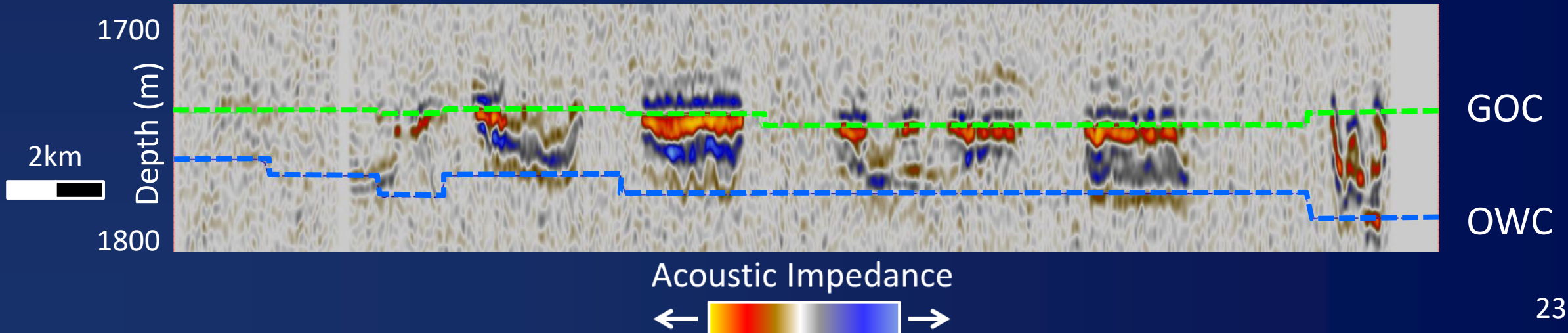


Fine-Scale Model 4D Seismic

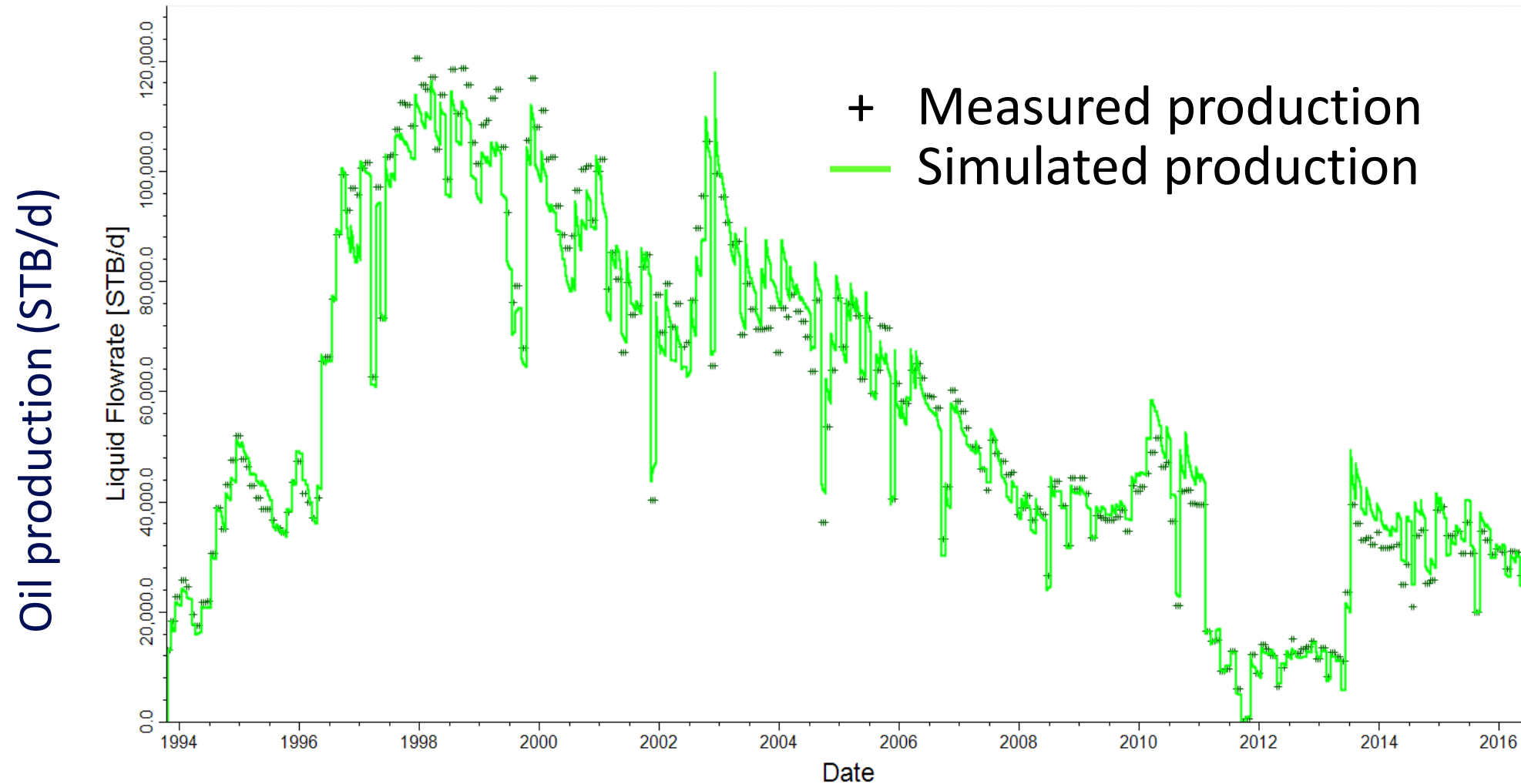
Real 4D Seismic Difference



Model 4D Seismic Difference












Production History Match



Pressure History Match



Seismic History Matching Summary

Model	Geological Description	History Match	4D Seismic Match
Initial model			
Updated model			
Fine-Scale model			

 Poor

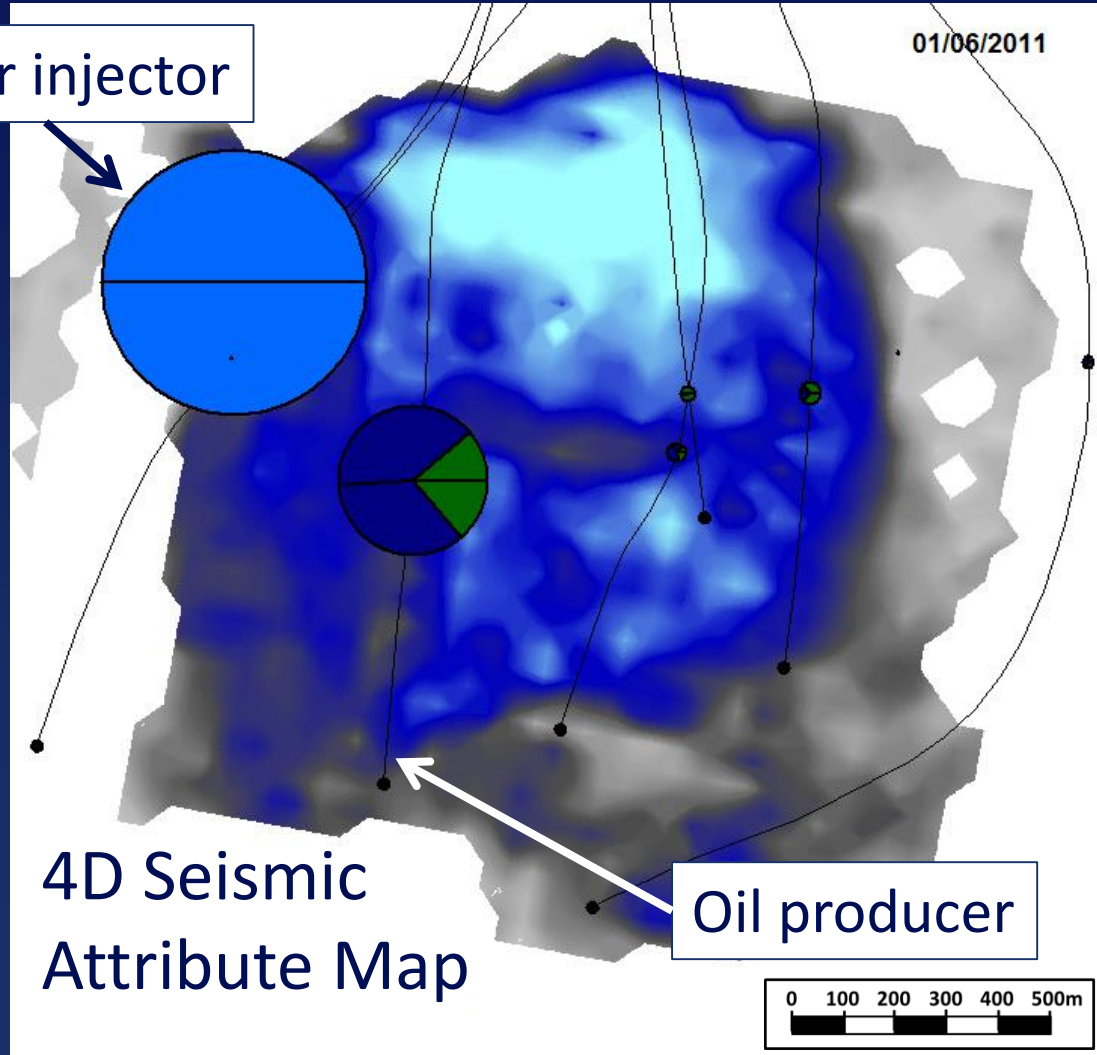
 Moderate

 Good

4D Assisted Seismic History Matching

Water injector

01/06/2011

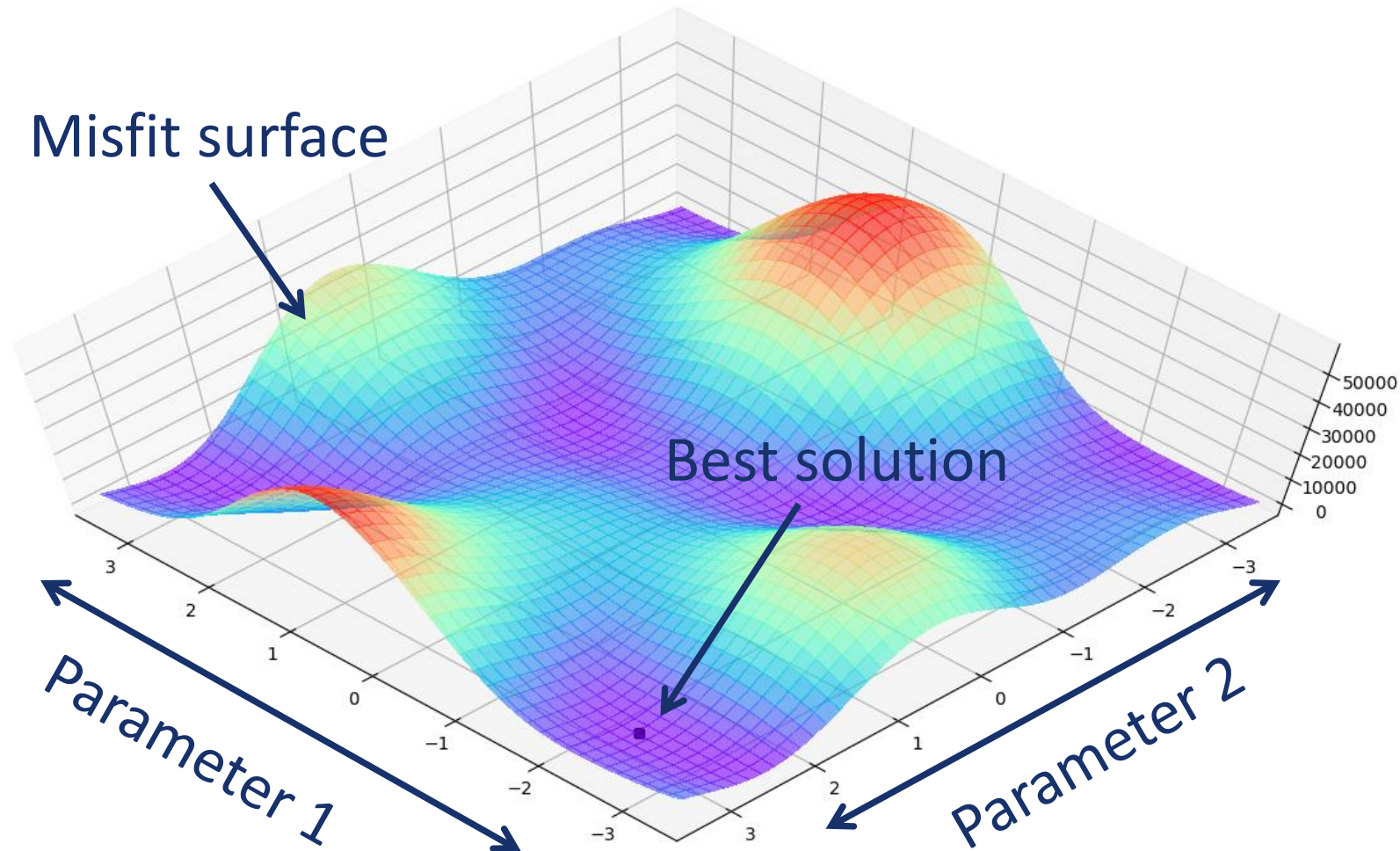


4D Seismic
Attribute Map

Oil producer

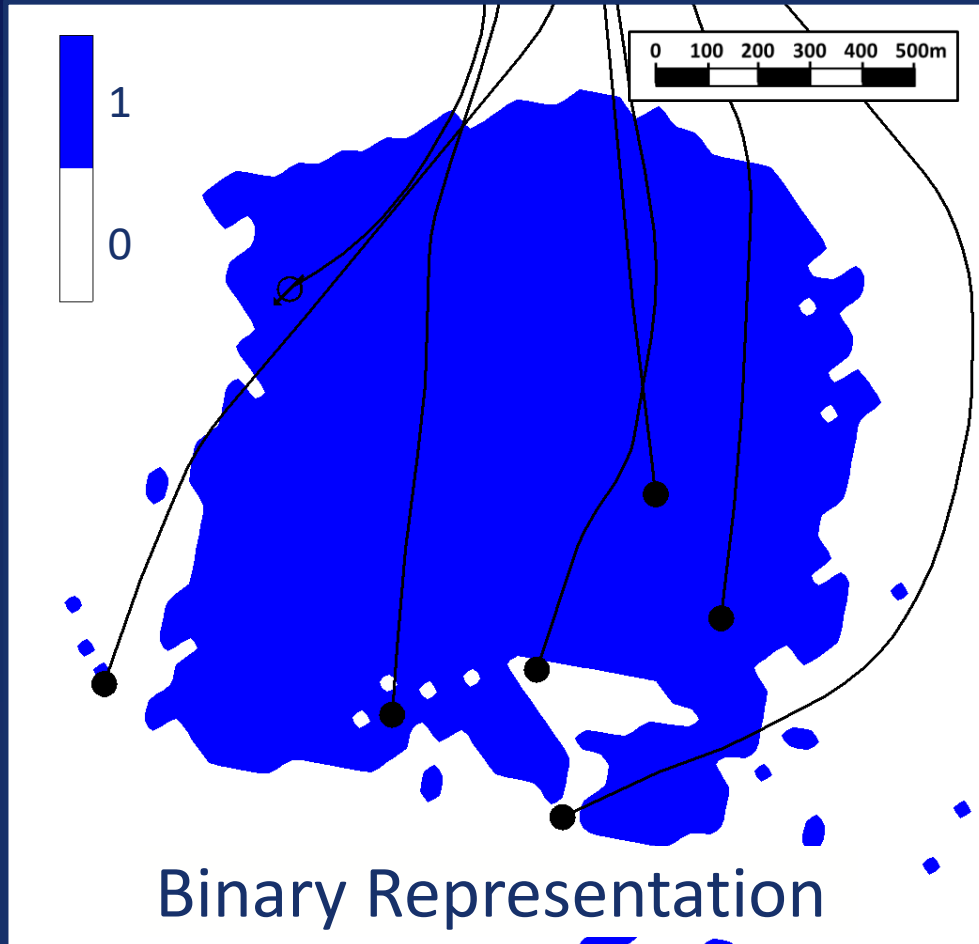
- Quantitative
- Automatic
- Intelligent

Genetic Algorithm for 4D ASHM

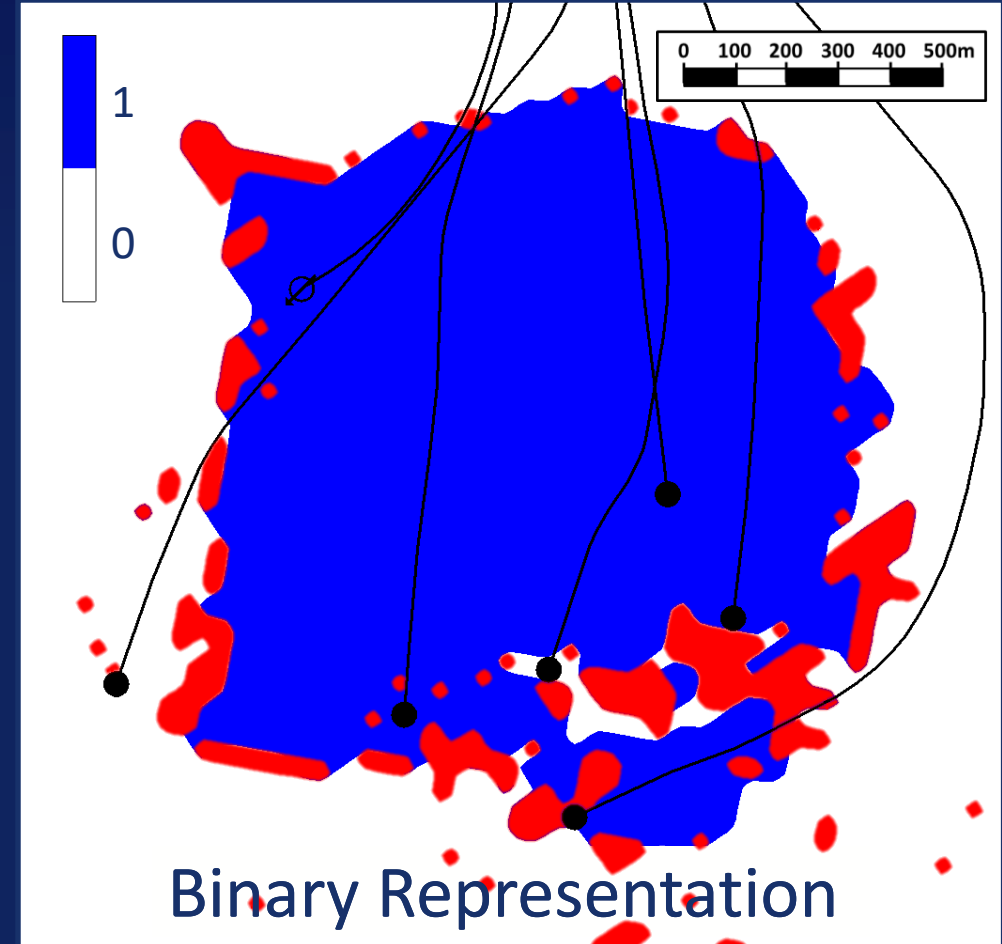


Quantitative 4D Analysis

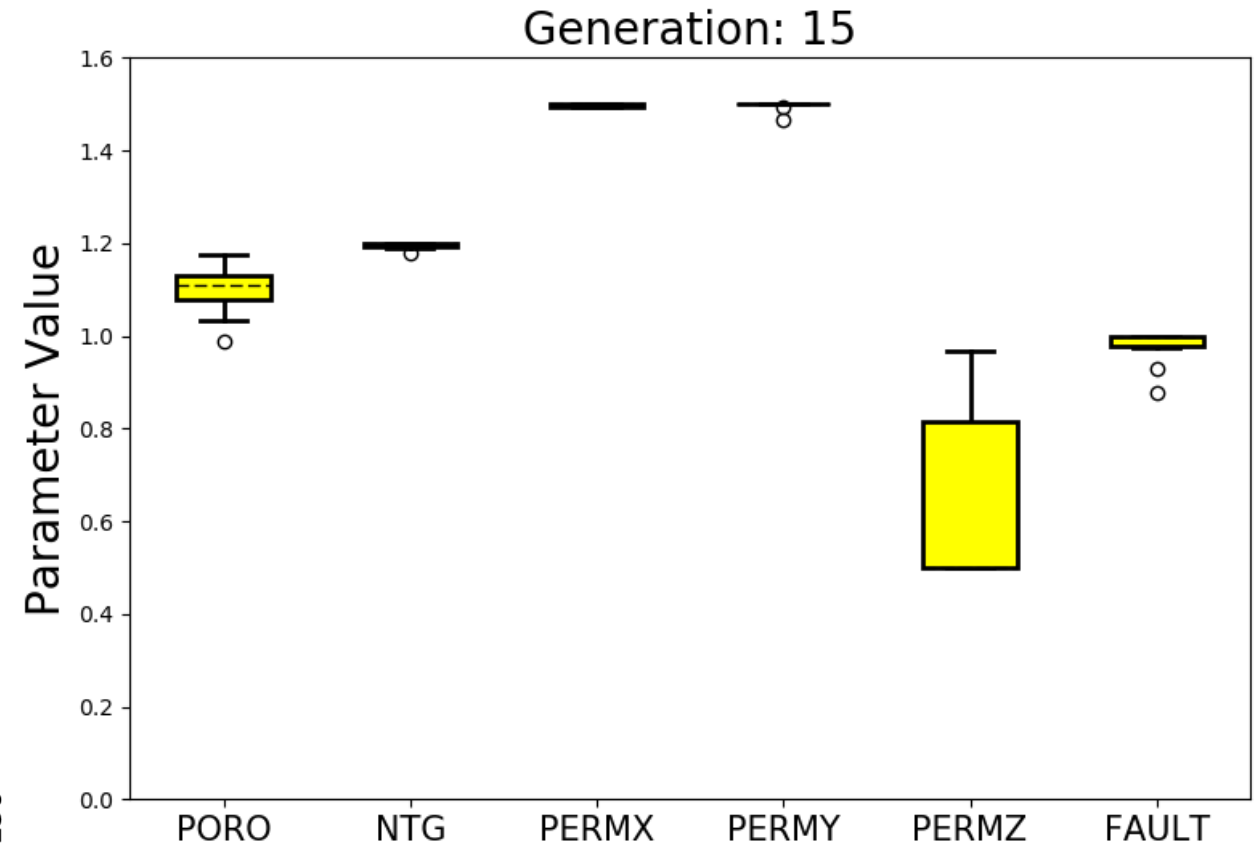
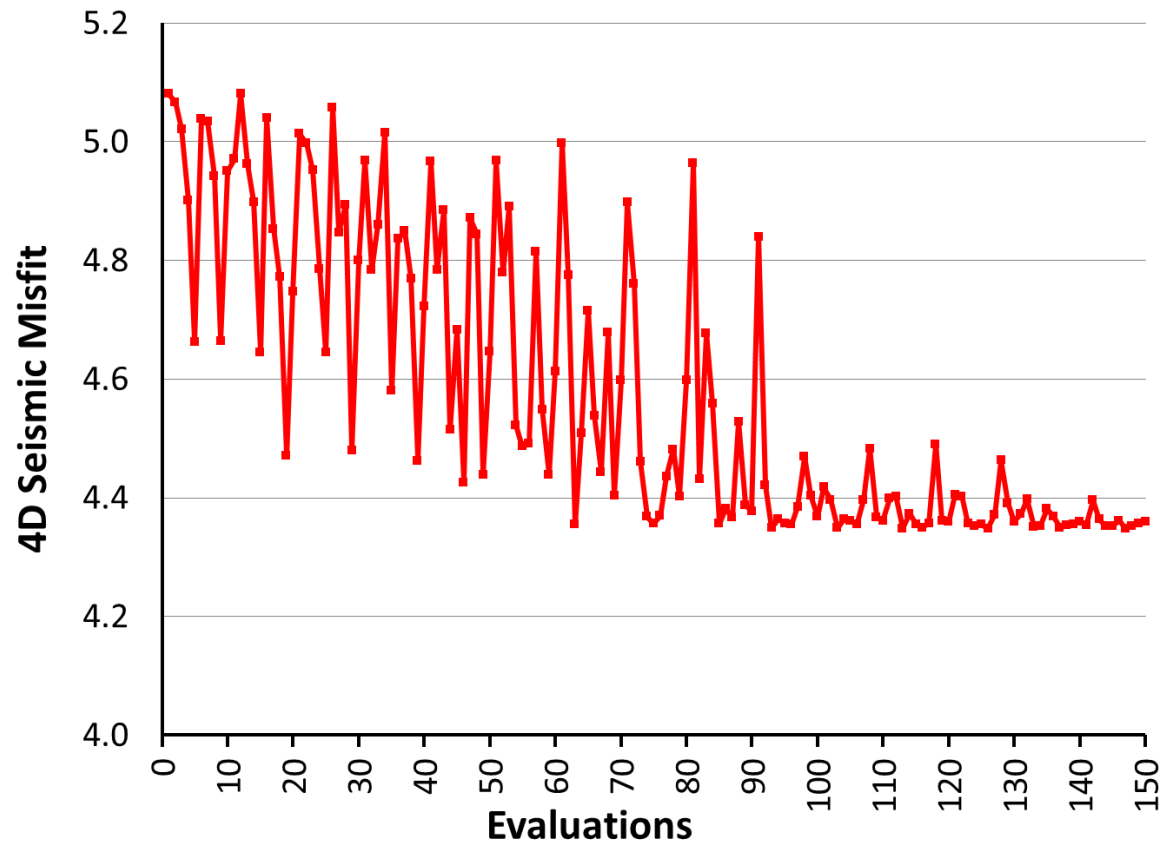
Real 4D Seismic Attribute Map



Model 4D Seismic Attribute Map

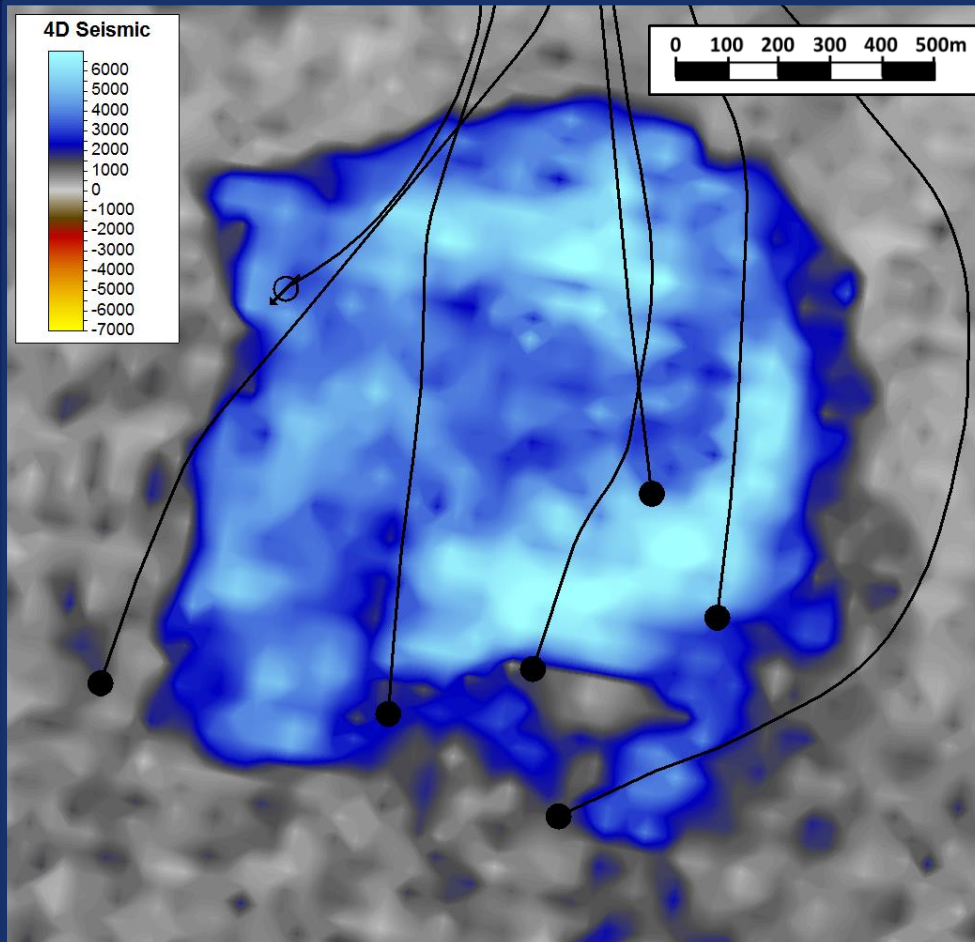


4D ASHM – Harding South Results

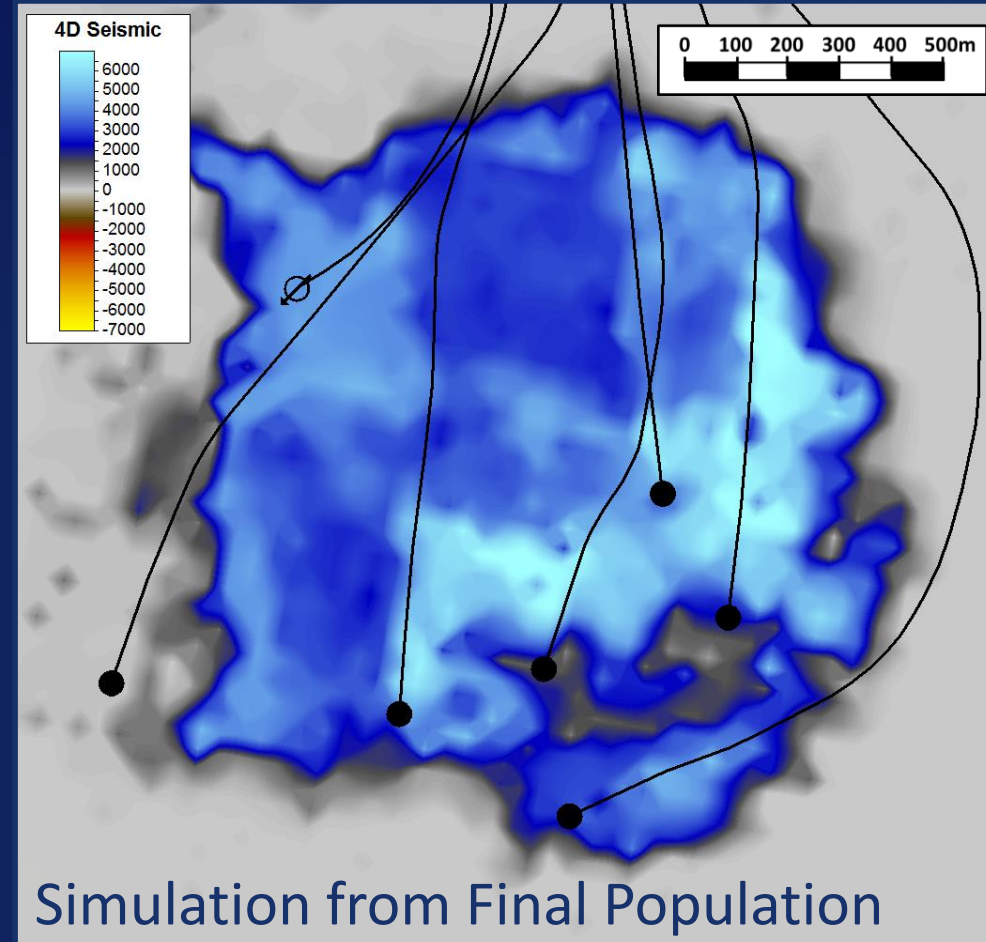


4D ASHM – Harding South Results

Real 4D Seismic Attribute Map

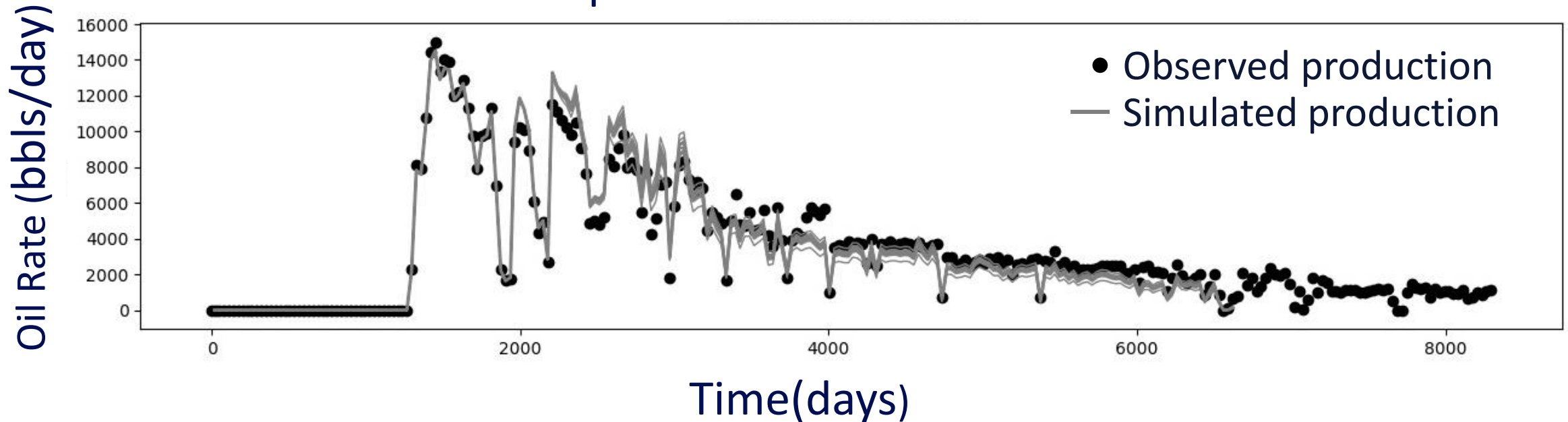


Model 4D Seismic Attribute Map



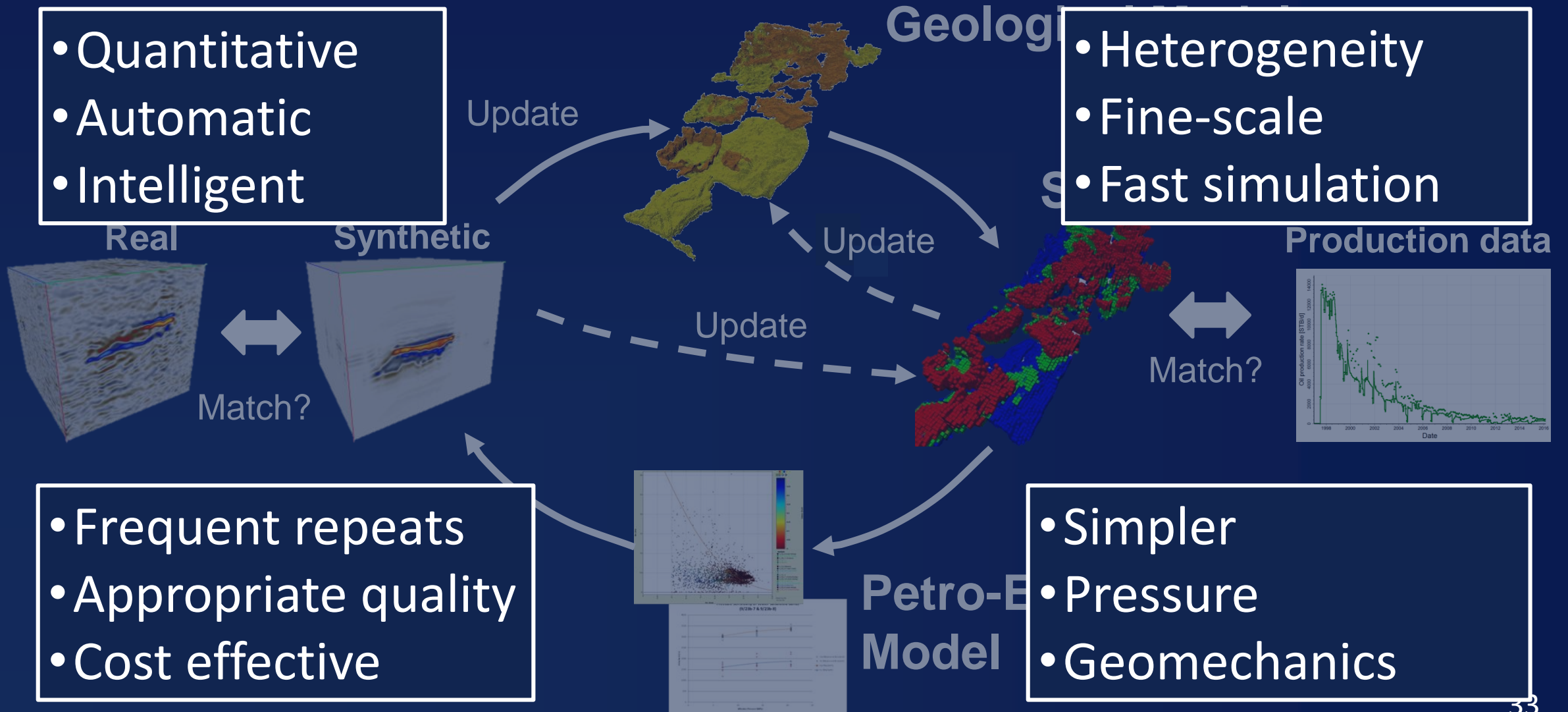
4D ASHM – Harding South Well Results

Final Population Oil Production Rate



4D ASHM using seismic improved production history match

Future Directions for SHM



Summary and Conclusions



- Seismic History Matching (SHM) uses 4D seismic data for improved reservoir models
- It describes the dynamic behaviour of the reservoir and the underlying geology
- It is an evolving technology that integrates all aspects of reservoir description

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