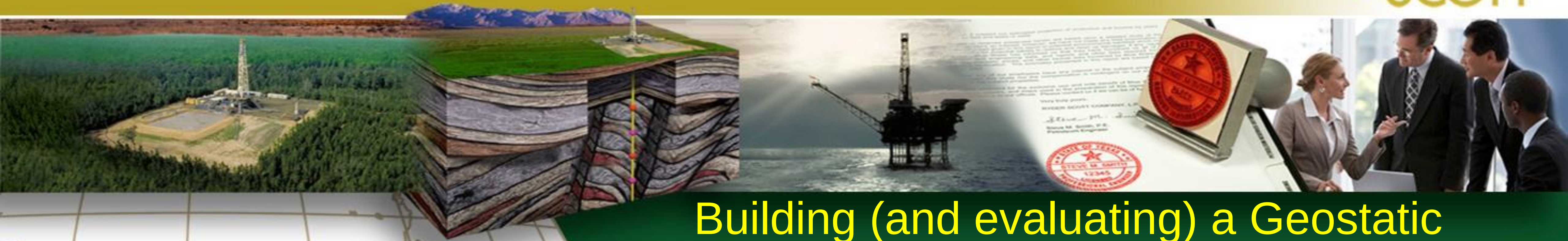


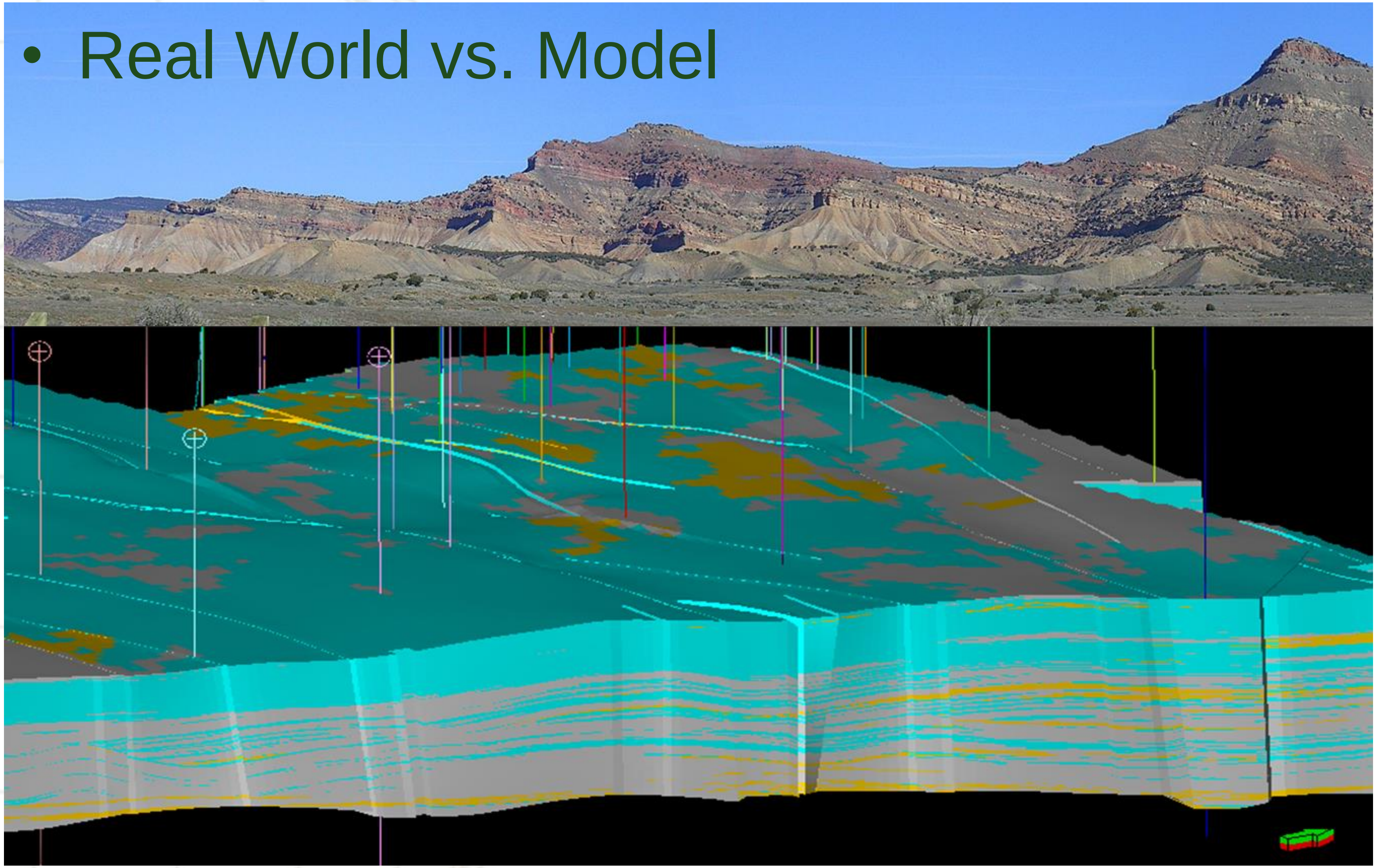
Building (and evaluating) a Geostatic Model for the Purpose of 1P, 2P & 3P Reserves Estimation

Steve Phillips

Ryder Scott Company

Geological Models

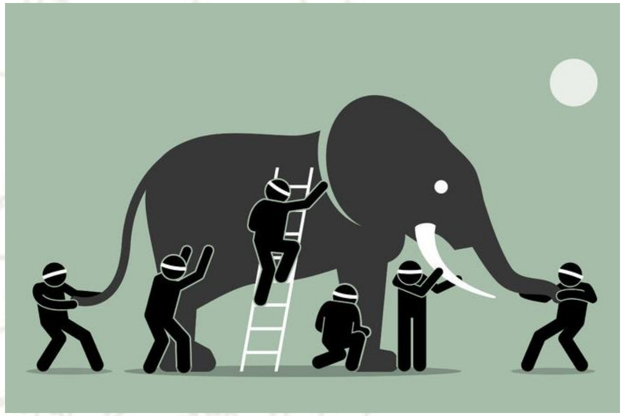
- Real World vs. Model



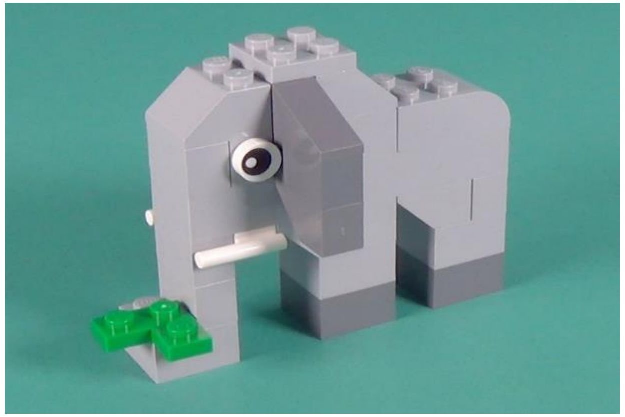
- What kind of animal?

Real World

Data



Model



$

Imperfect sampling and measurement

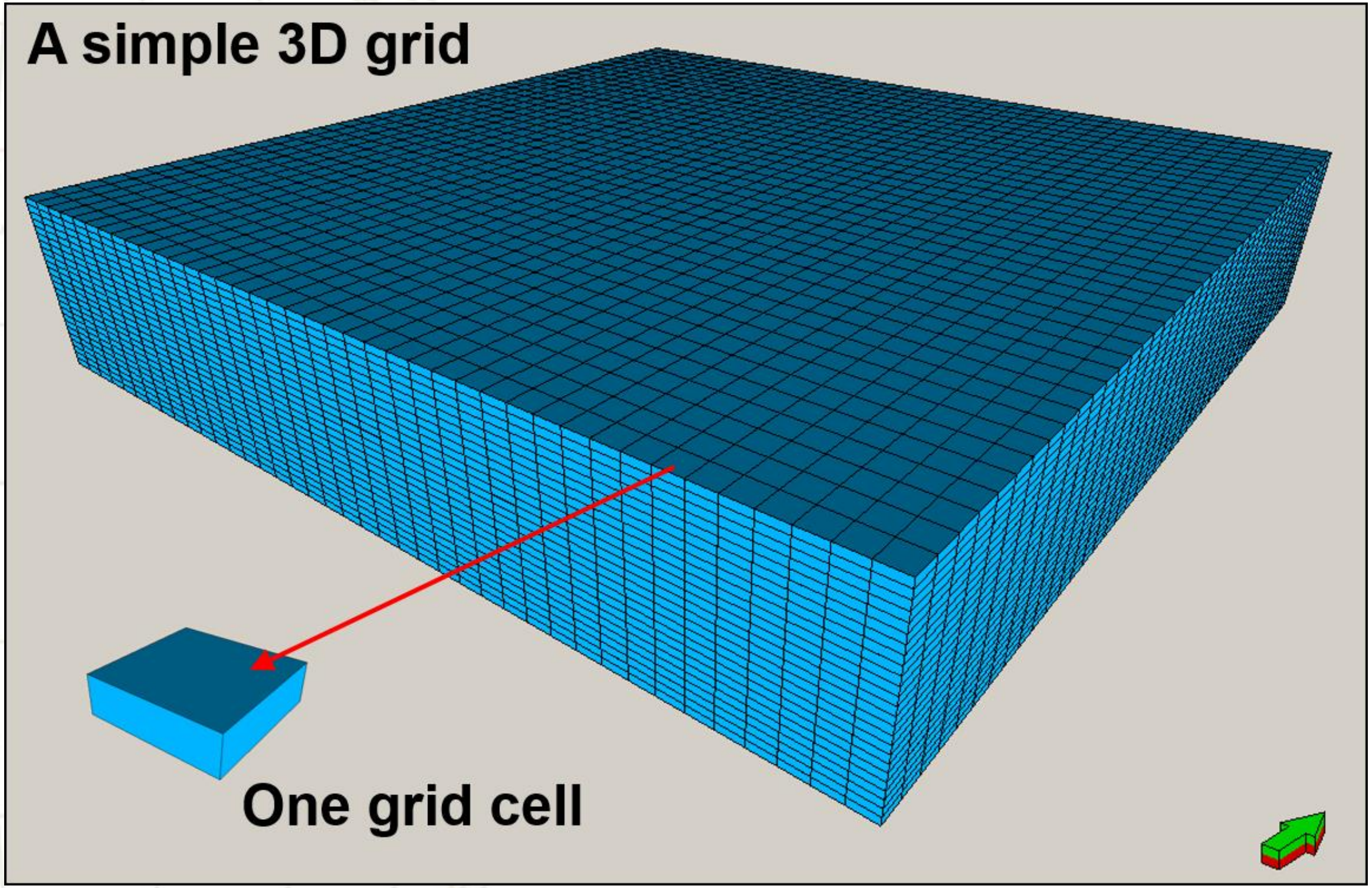
Imperfect interpretation, software and execution

PIIP, EUR, 1P, 2P, 3P Value

Goal of any reservoir model?

- Accurately describe observed rock and fluid properties from data.
- Reliably characterize calculated rock and fluid properties based on interpretation.
- Document best technical PIIP estimate, associated Key Volumetric Uncertainties (Static).
- Define fluid flow units, support history match and forecast (Dynamic).
- **In reserves certifications: All of the above, *plus facilitate application of resource definitions***

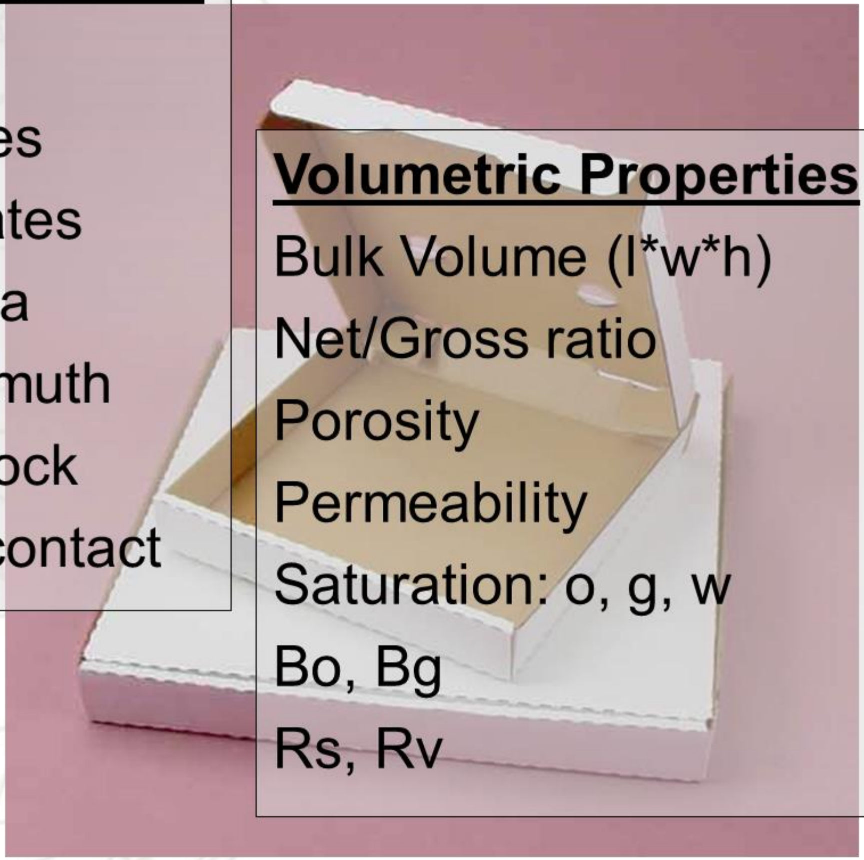
3D Models – Geology in a Box



3D Models – Geology in a Box

Geometric Properties

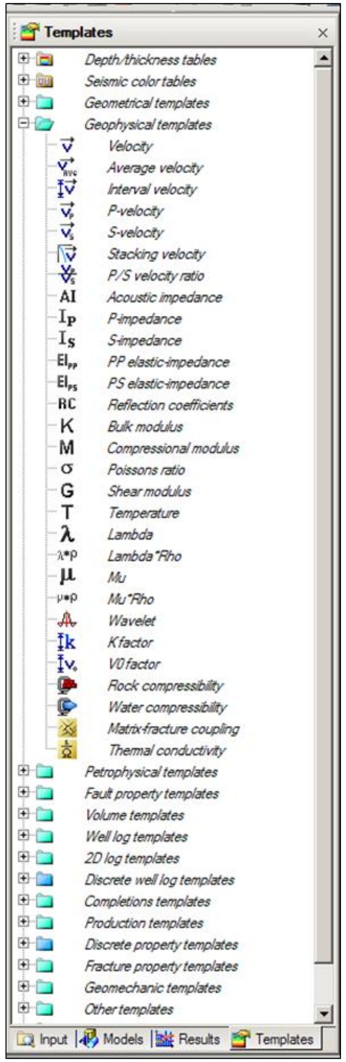
Depth (Z)
X, Y coordinates
I, J, K coordinates
Thickness, Area
Dip: angle, azimuth
Layer, Fault Block
Height above contact



Volumetric Properties

Bulk Volume (l*w*h)
Net/Gross ratio
Porosity
Permeability
Saturation: o, g, w
Bo, Bg
Rs, Rv

Many Others

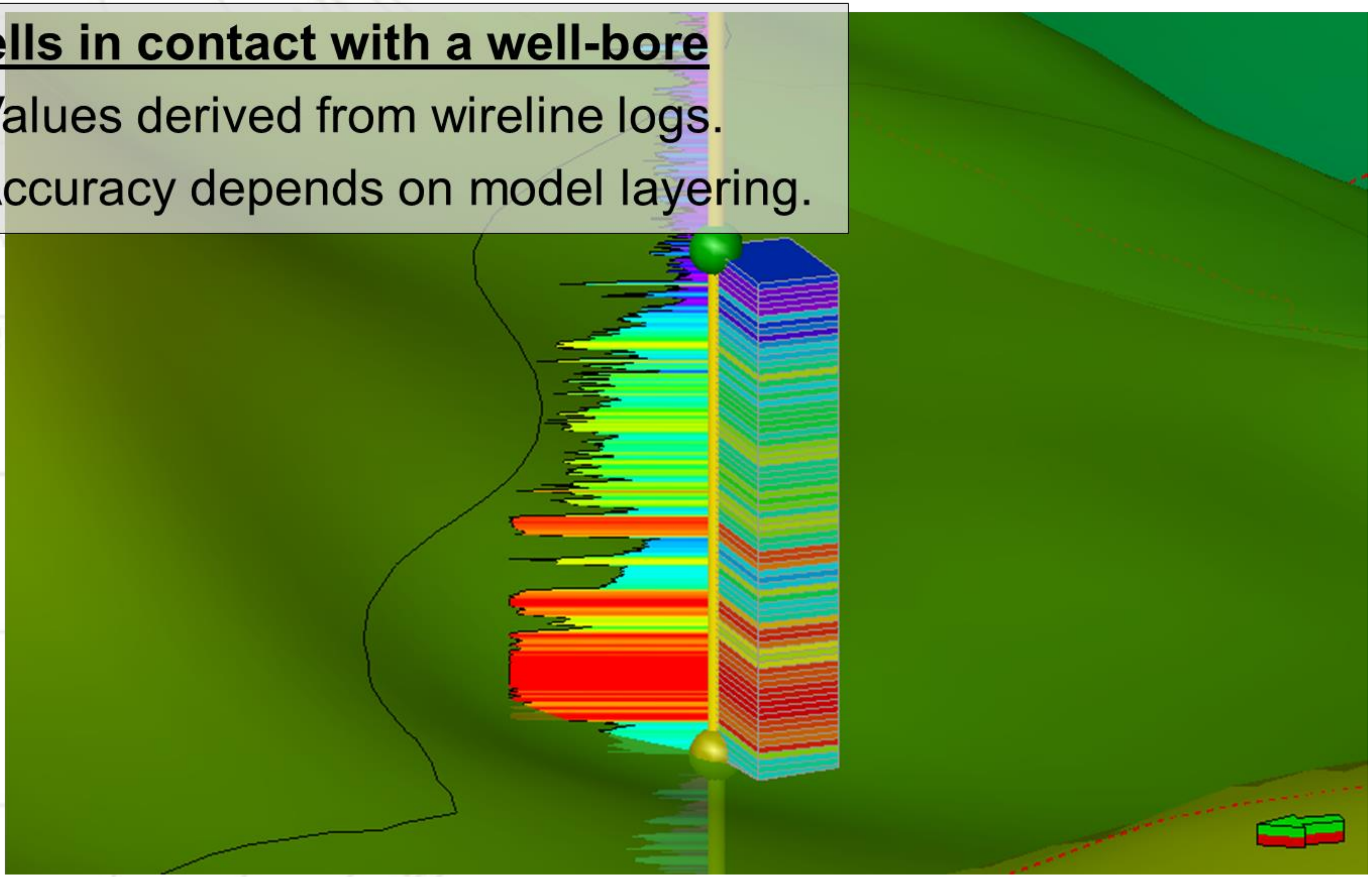


3D Models – Geology in a Box

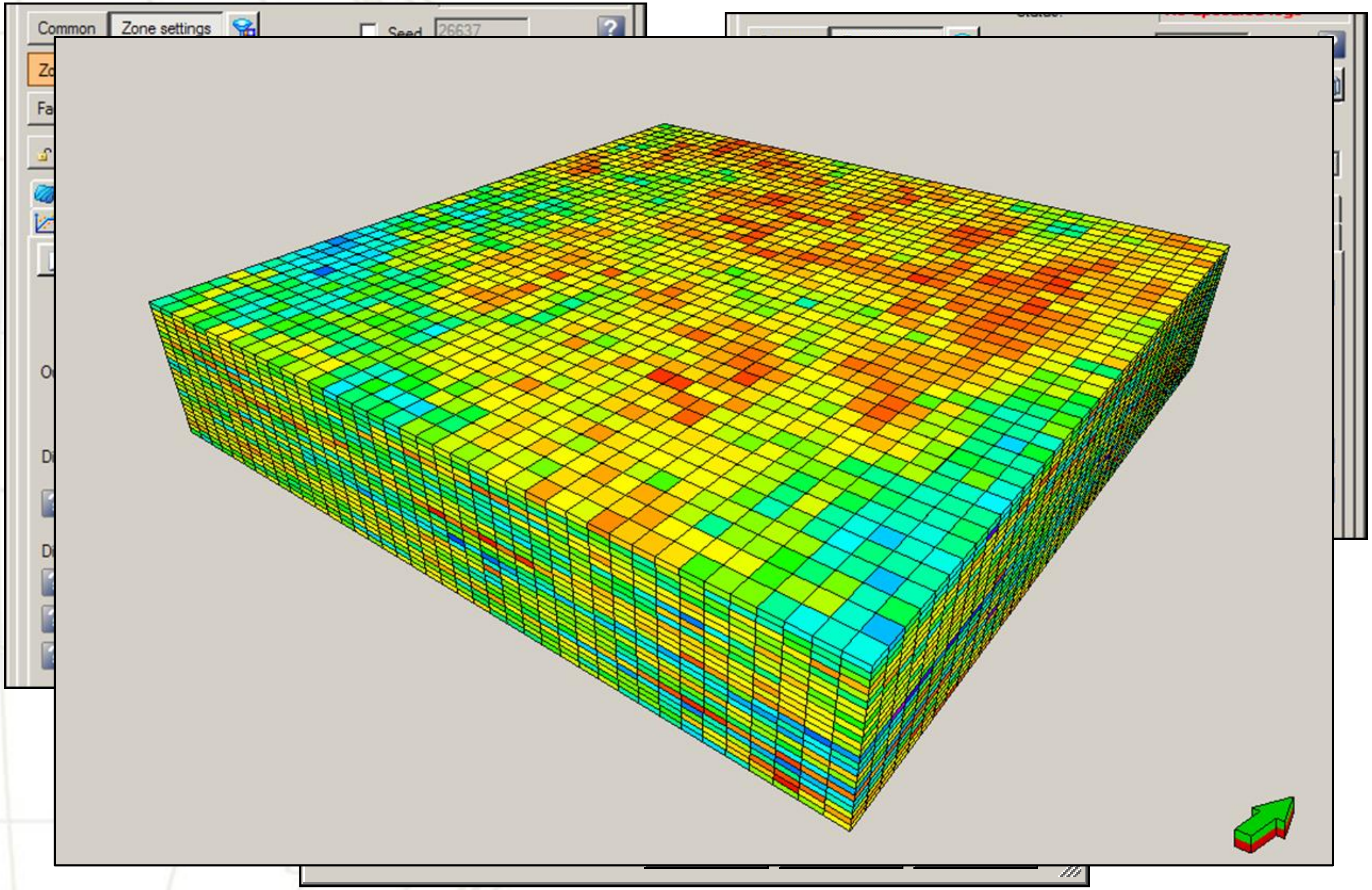
Cells in contact with a well-bore

Values derived from wireline logs.

Accuracy depends on model layering.



3D Models – Geology in a Box



3D Models: Strengths and Weaknesses

Strengths	Weaknesses*
Data integration	MANY potential workflows
Geometrical constraints	MANY parameter options
Spatial relationships	Proliferation of models
Geostatistics	Potential to hide bad geology
Visualization	Maps, Xsecs often ignored
Scenario testing	Documentation
Updates	Updates

*Also true for traditional methods.

PRMS: Reservoirs and Projects

Provide a spatial framework for application of reserves/resources definitions

<u>Discovered</u>

A petroleum accumulation…a significant quantity of potentially recoverable hydrocarbons….

<u>Discovered PIIP</u>

Quantity of petroleum that is estimated, as of a given date, to be contained in known accumulations before production….

<u>Discovered Unrecoverable</u>

Discovered petroleum in-place …not able to be recovered by the commercial and sub-commercial projects envisioned.

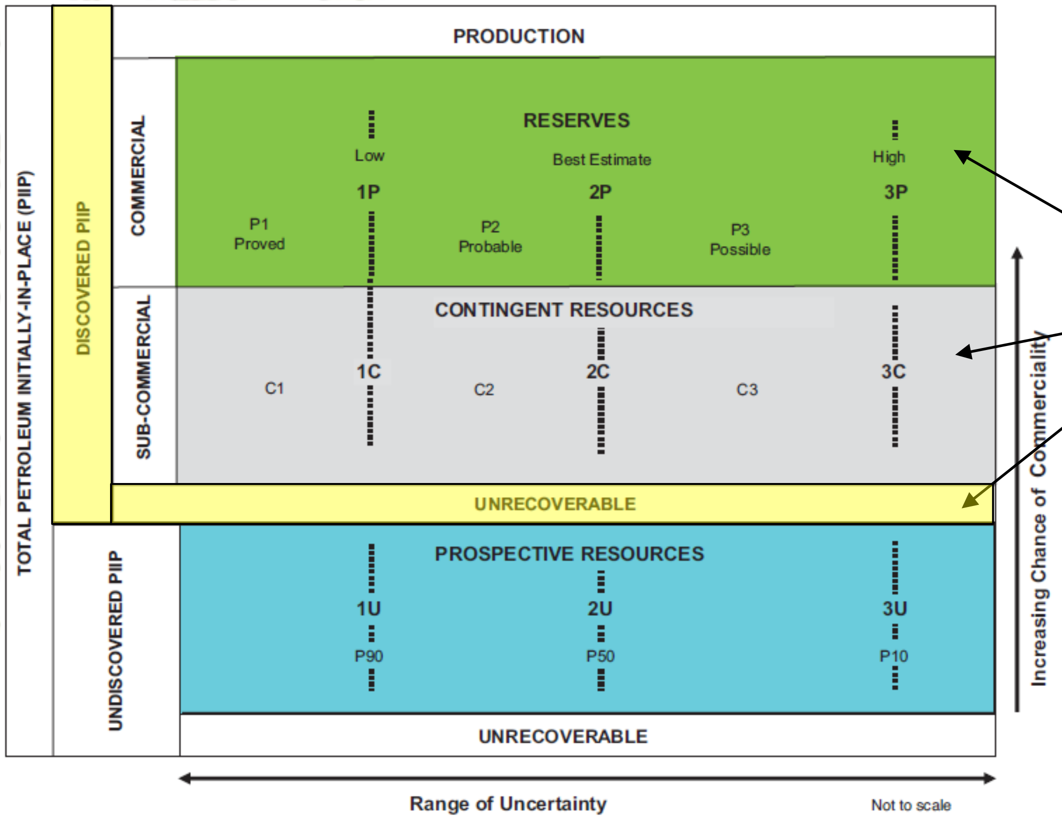


Figure 1.1—Resources classification framework

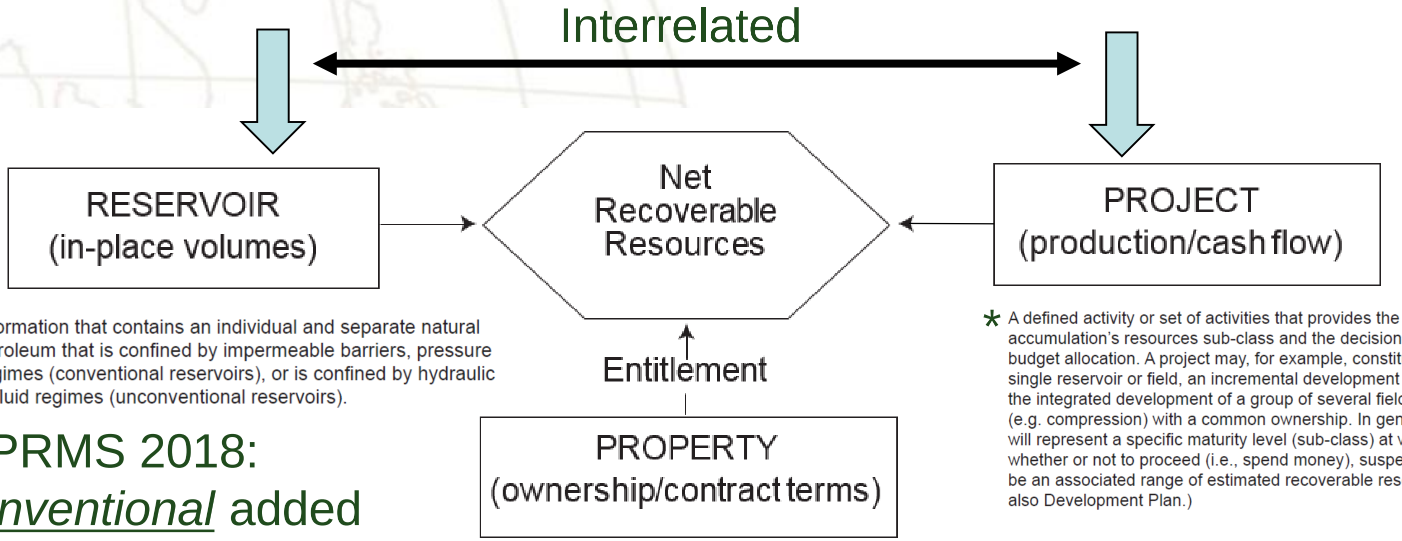
A 3D model must discriminate rock volumes contributing to <u>resources</u> and <u>reserves</u> from rock volumes containing only <u>unrecoverable</u> oil and gas or volumes beyond scope of <u>project</u>

Source: Petroleum Resources Management System, June, 2018

PRMS: Reservoirs and Projects

Discriminate rock volumes that comply with definition of a reservoir* from volumes that do not.

Associate appropriate oil or gas in-place volumes with defined recovery project*.



* A subsurface rock formation that contains an individual and separate natural accumulation of petroleum that is confined by impermeable barriers, pressure systems, or fluid regimes (conventional reservoirs), or is confined by hydraulic fracture barriers or fluid regimes (unconventional reservoirs).

* A defined activity or set of activities that provides the link between the petroleum accumulation's resources sub-class and the decision-making process, including budget allocation. A project may, for example, constitute the development of a single reservoir or field, an incremental development in a larger producing field, or the integrated development of a group of several fields and associated facilities (e.g. compression) with a common ownership. In general, an individual project will represent a specific maturity level (sub-class) at which a decision is made on whether or not to proceed (i.e., spend money), suspend, or remove. There should be an associated range of estimated recoverable resources for that project. (See also Development Plan.)

PRMS 2018:
Unconventional added
Moveable removed

Figure 1.2—Resources evaluation

1.2.0.3 ***The reservoir*** (contains the petroleum accumulation): Key attributes include the types and quantities of PIIP and the fluid and rock properties that affect petroleum recovery.

Source: Petroleum Resources Management System, June, 2018

PRMS: Reservoirs and Projects

Conceptual Diagram of a Rock Volume
with Variable Properties.
Black = Best Producibility.
Not to Scale.

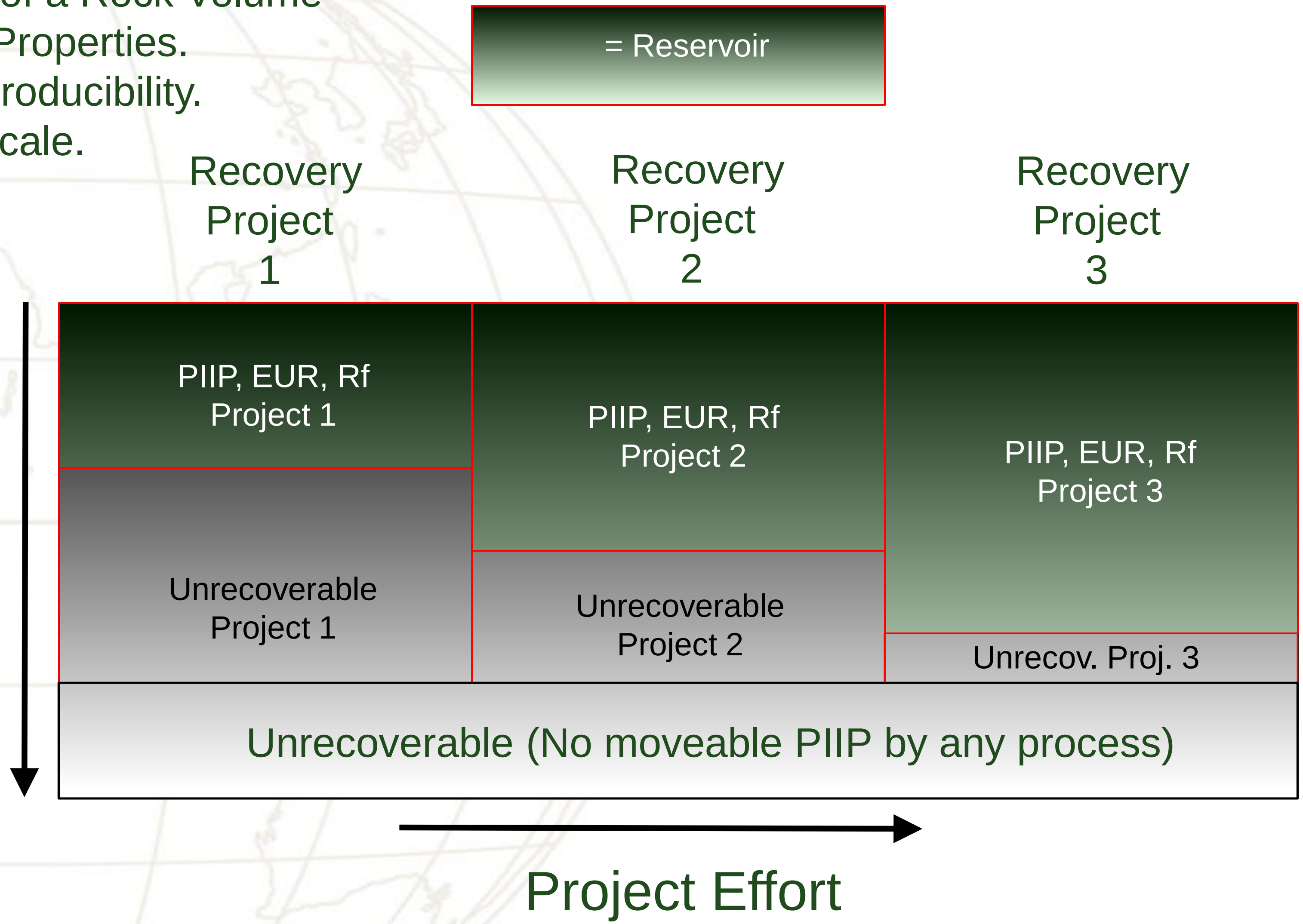
Decreasing Rock and/or Fluid Quality

For Example:

Lower Porosity, Permeability, HC Saturation, Oil Mobility

Less Continuous, Fractured

Separated by a barrier to fluid flow



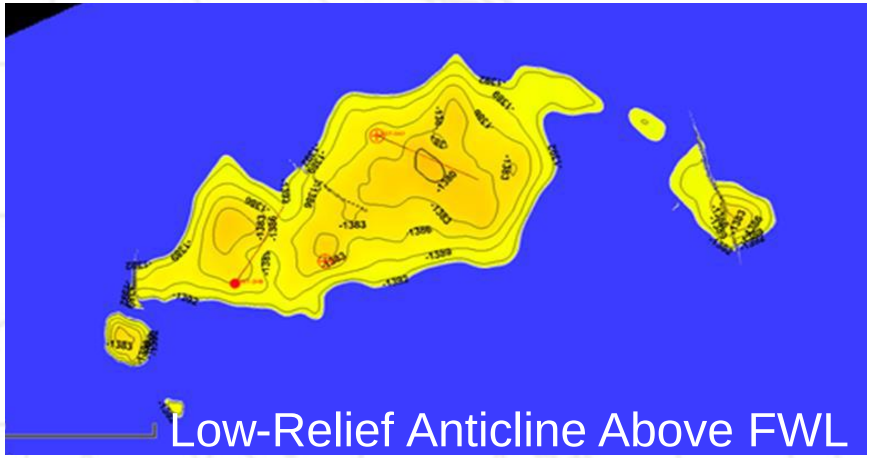
Recommendations

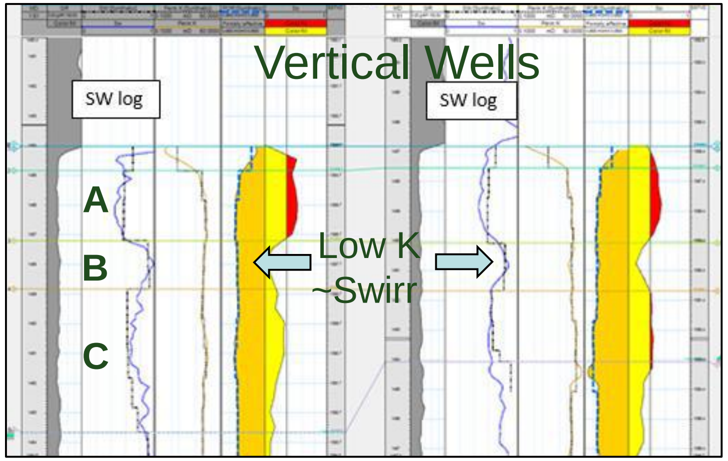
Design model to accommodate known and potential projects.

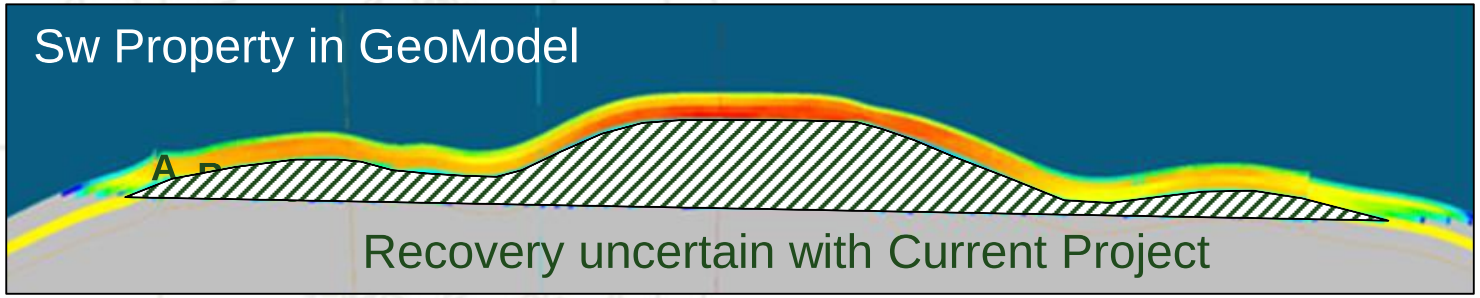
Adjust Vnet with cut-offs that exclude unrecoverable volumes.

Include all potential barriers to fluid flow.

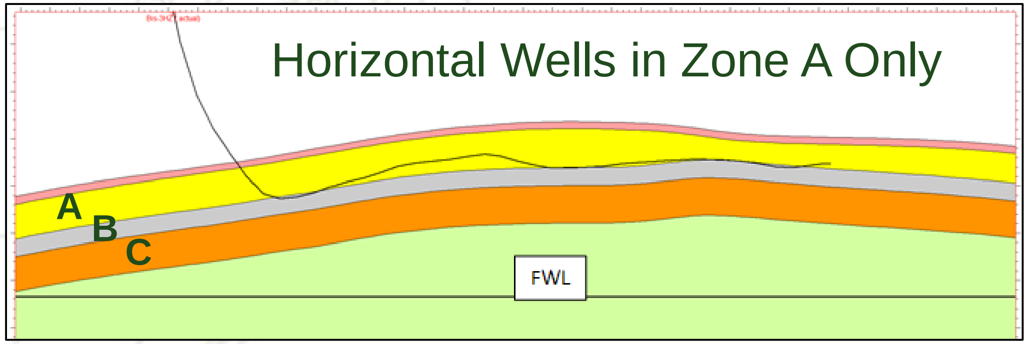
Example: Carbonate





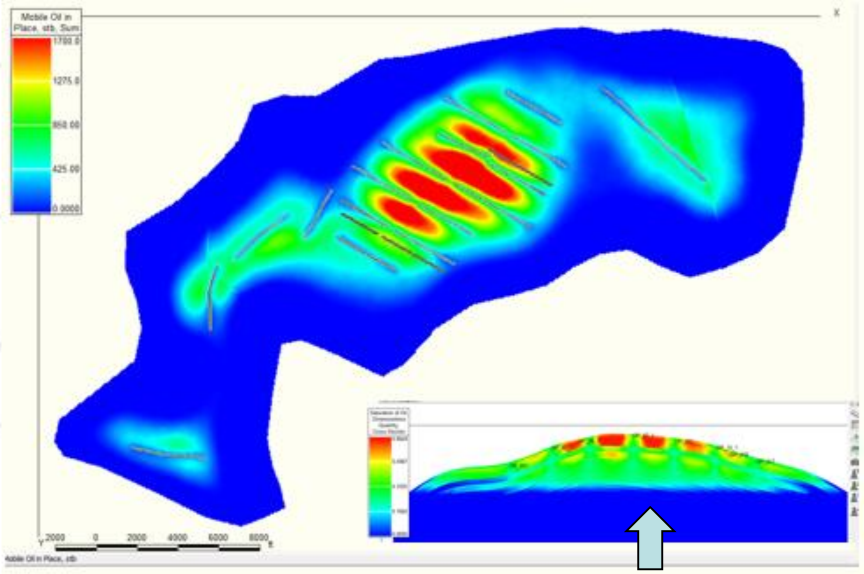


Quick-look opinion:
Reasonable static model

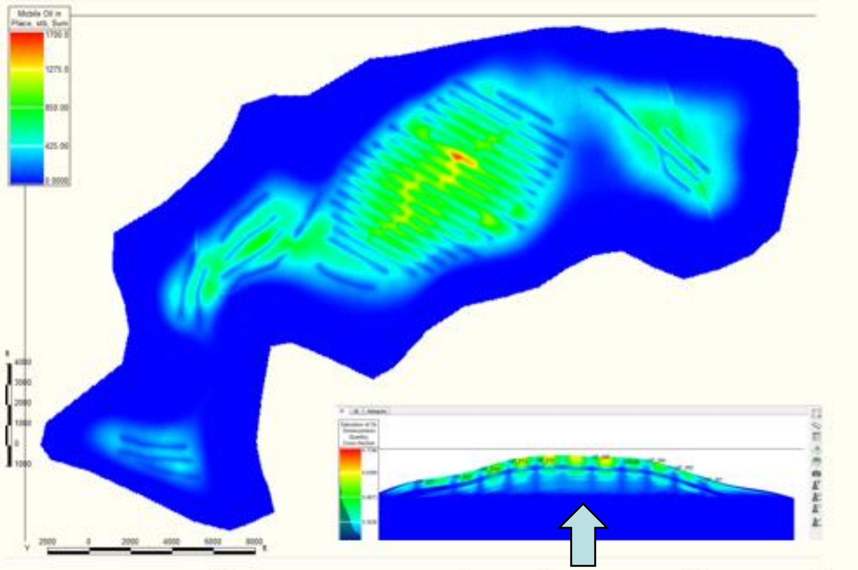


Question: Are Zones B and C reservoirs for the horizontal well project?

Example: Carbonate



Remaining oil after 20 years of production with **17 Wells**
Cum Oil Recovery: 8.2mmbo, **RF 9%**



Remaining oil after 20 years of production with **49 Wells**
Cum Oil Recovery: 19.4mmbo **RF 21%**

Simulated recovery from Zones B and C depends on project effort.

1P-2P-3P Reserves from Zones B and C? With 49 wells?

Opinion: With caution. Observed response helpful.

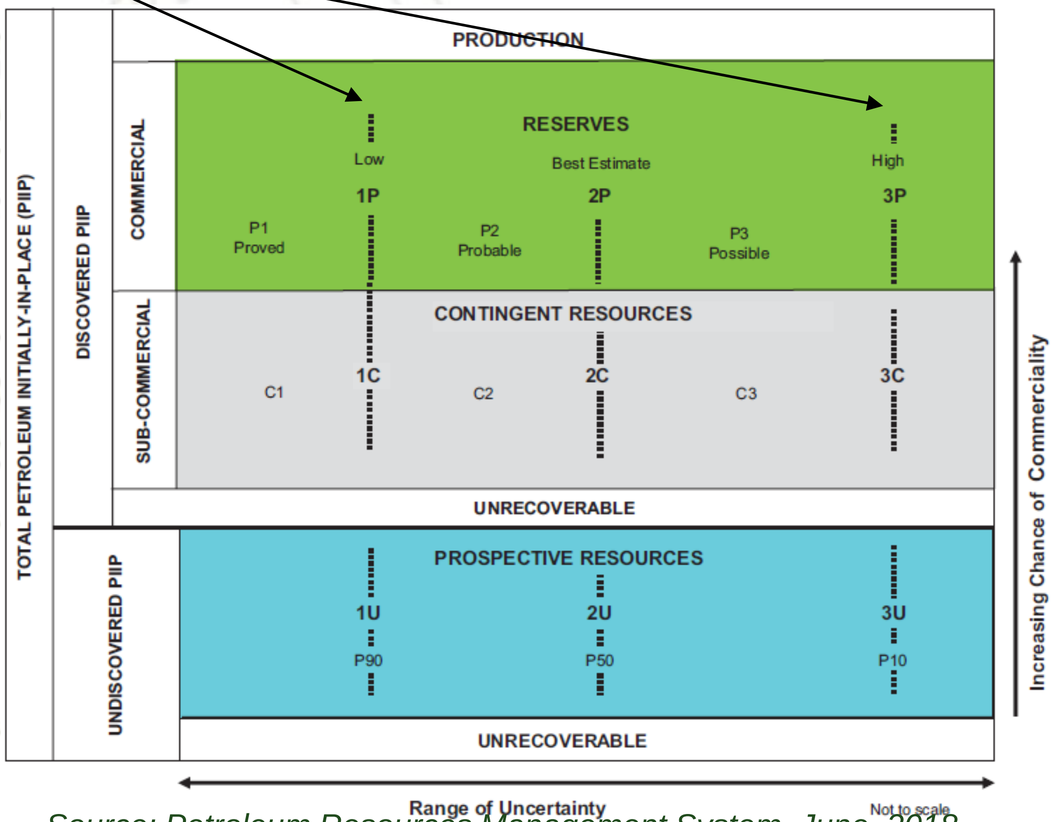
RF = EUR / PIIP

- Recovery factor is the essential link between engineering and geoscience.
- Meaningful PIIP estimations must relate to EUR.
- EUR is defined by a project.
- Therefore, PIIP in a geomodel (or map) must be contained in a reservoir associated with a project.

PRMS: Key Volumetric Uncertainties

Provide a spatial framework for application of reserves/resources definitions

A 3D model must support deterministic interpretations of volume uncertainty categories.



Source: Petroleum Resources Management System, June, 2018

Figure 1.1—Resources classification framework

3D Geological Models Potentially Excellent Tools for Application of Reserves Categories

4.1.2.2 The key uncertainties affecting in-place quantities include but are not limited to the following:

A. Reservoir geometry, heterogeneity, compartmentalization, and trap limits that impact gross rock volume.

B. Geological characteristics that define pore volume and petroleum saturation distribution.

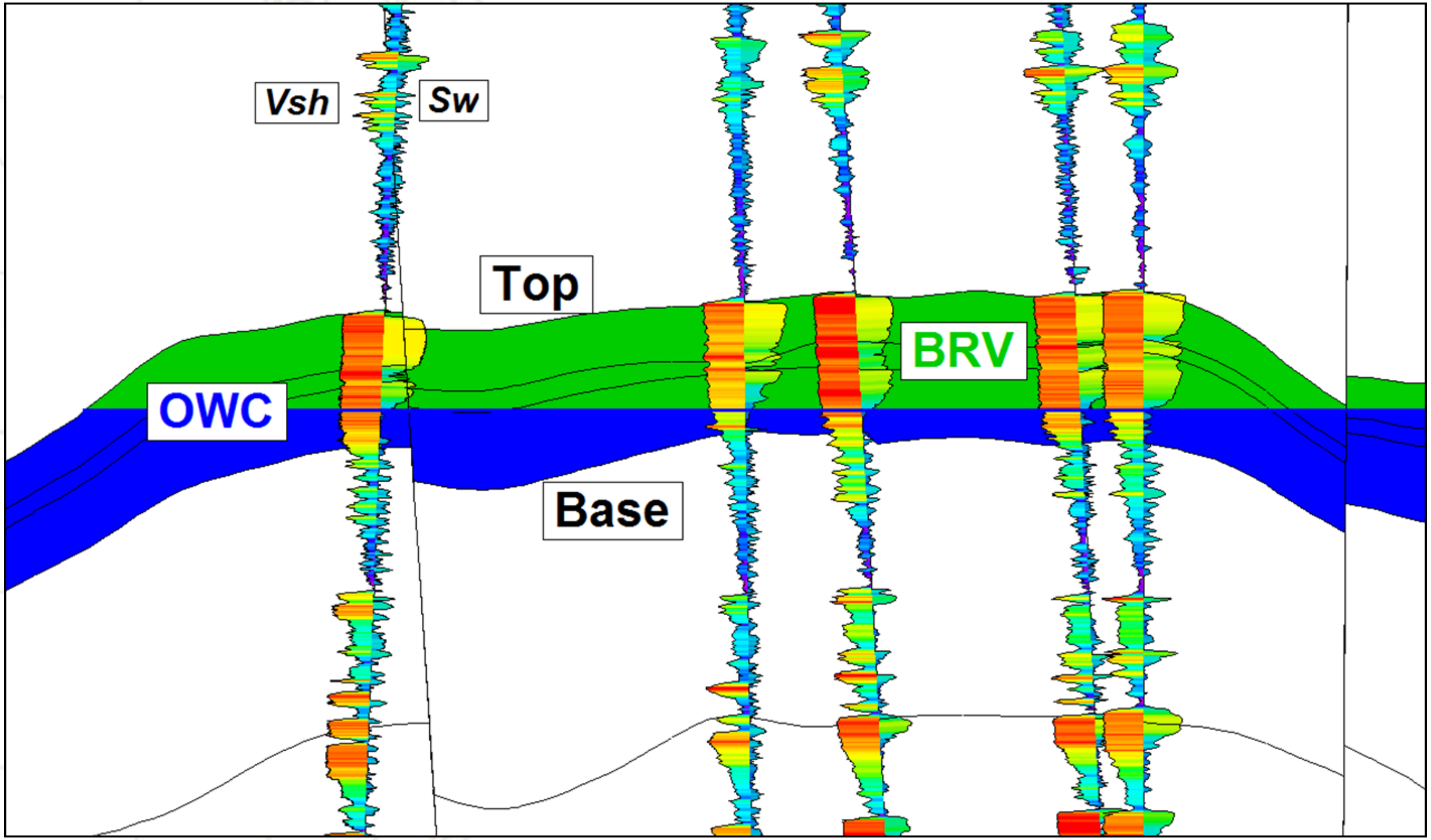
C. Position and nature of contacts or limits [e.g., lowest known hydrocarbons (LKH), oil/water contact, gas/water contact (GWC), gas/oil contact, and tilted contact gradient].

D. Combinations of reservoir quality, fluid types, and contacts that control saturation distributions (vertically and horizontally).

Source: Petroleum Resources Management System, June, 2018

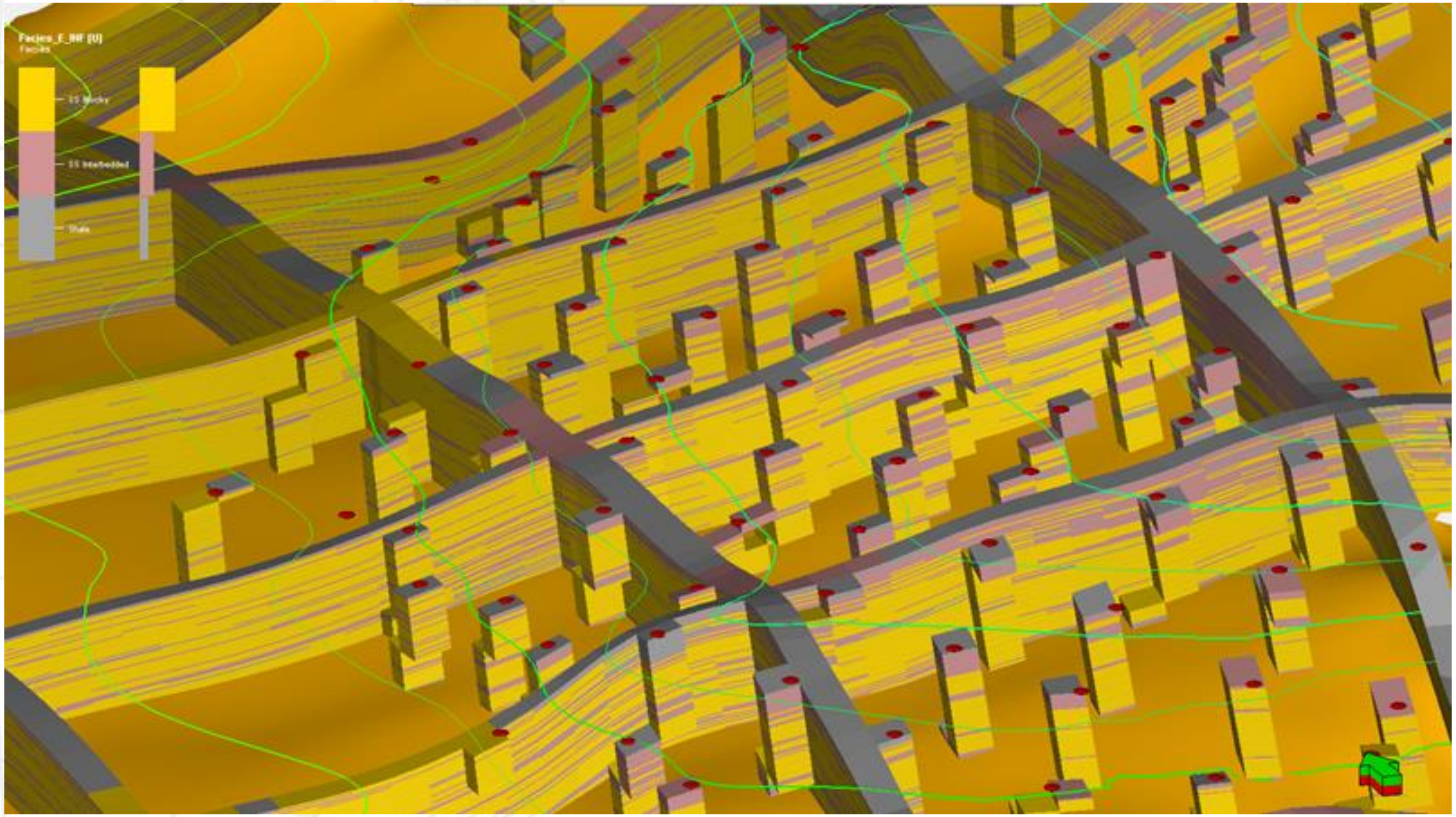
PRMS: Key Volumetric Uncertainties

- Geometry:



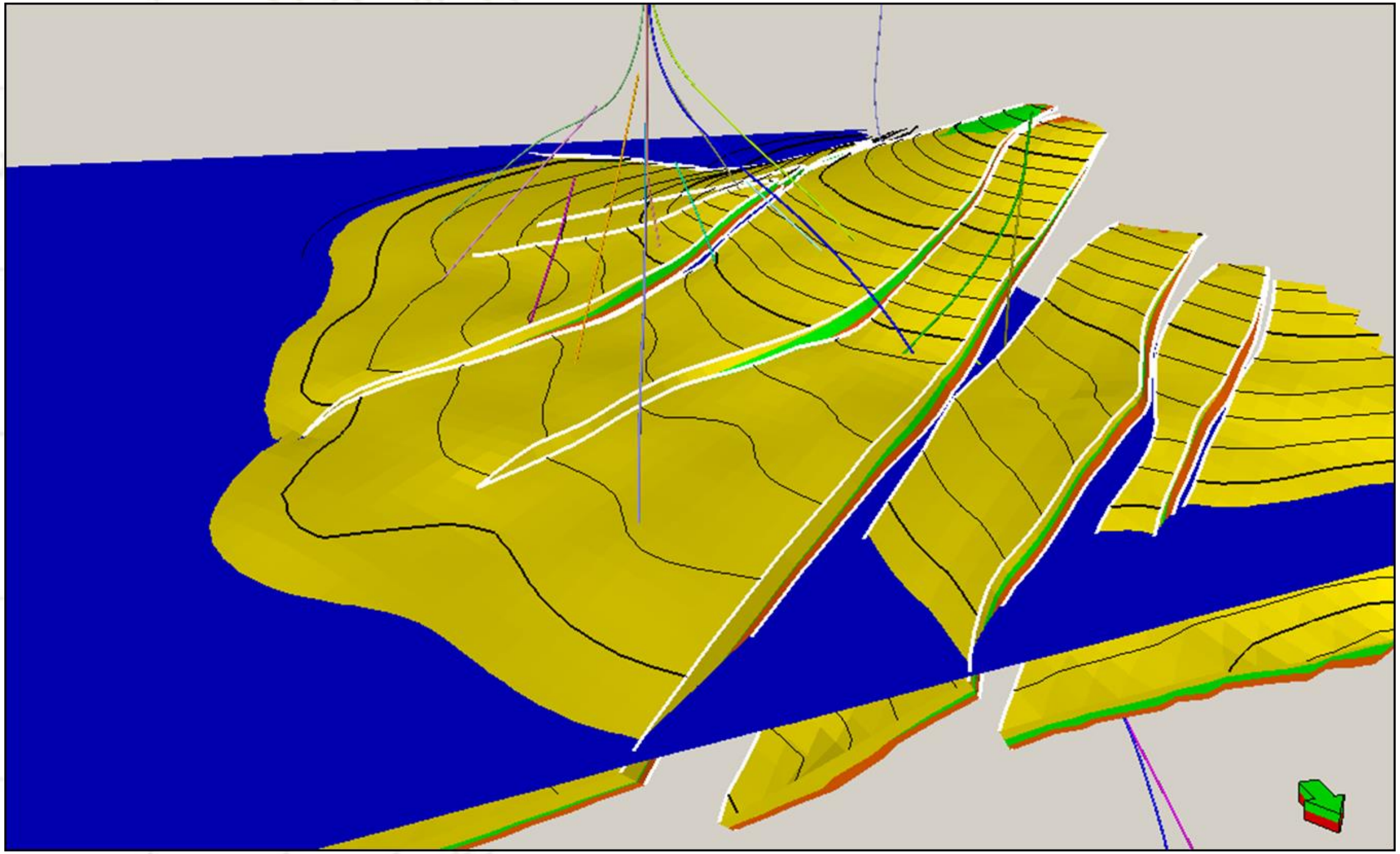
PRMS: Key Volumetric Uncertainties

- Heterogeneity:



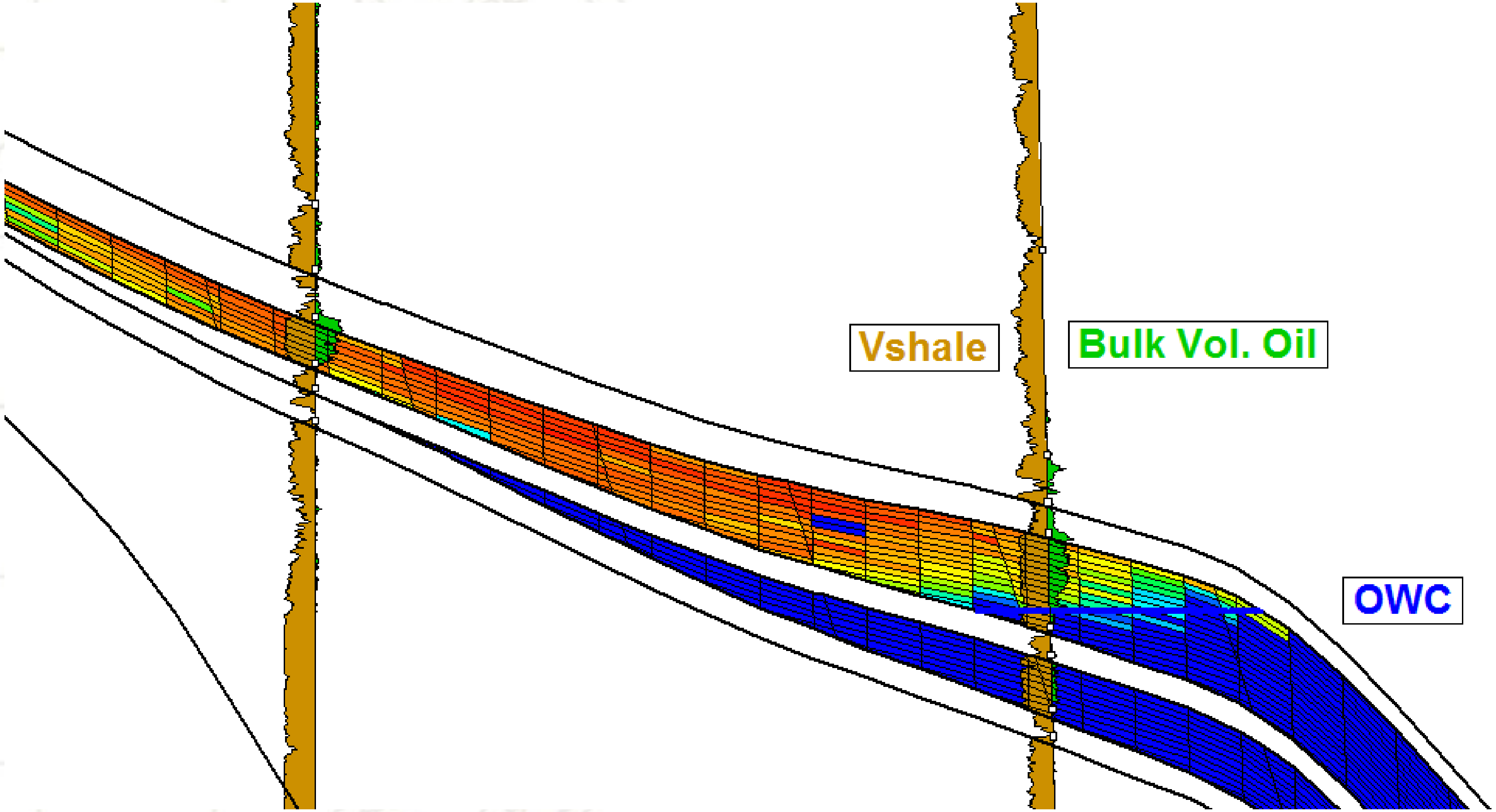
PRMS: Key Volumetric Uncertainties

- Compartmentalization:



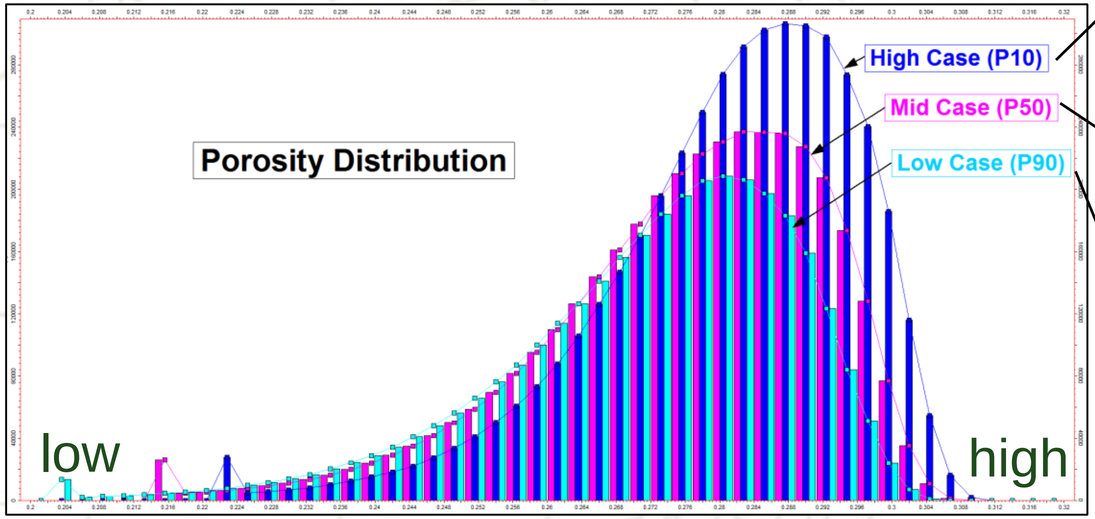
PRMS: Key Volumetric Uncertainties

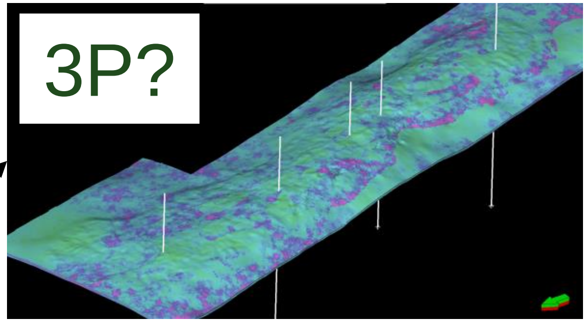
- Vpore, HC Saturation:

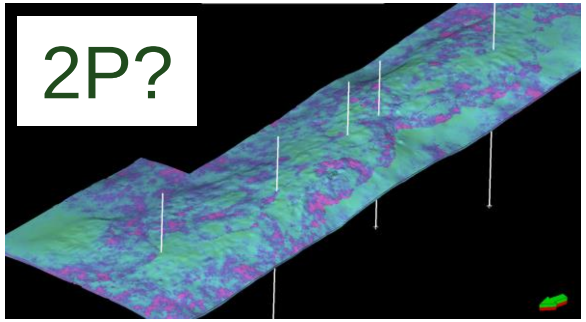


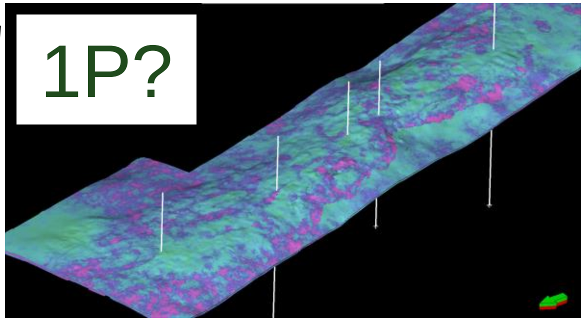
Example:

- <u>Pore Volume – deterministic scenario</u>





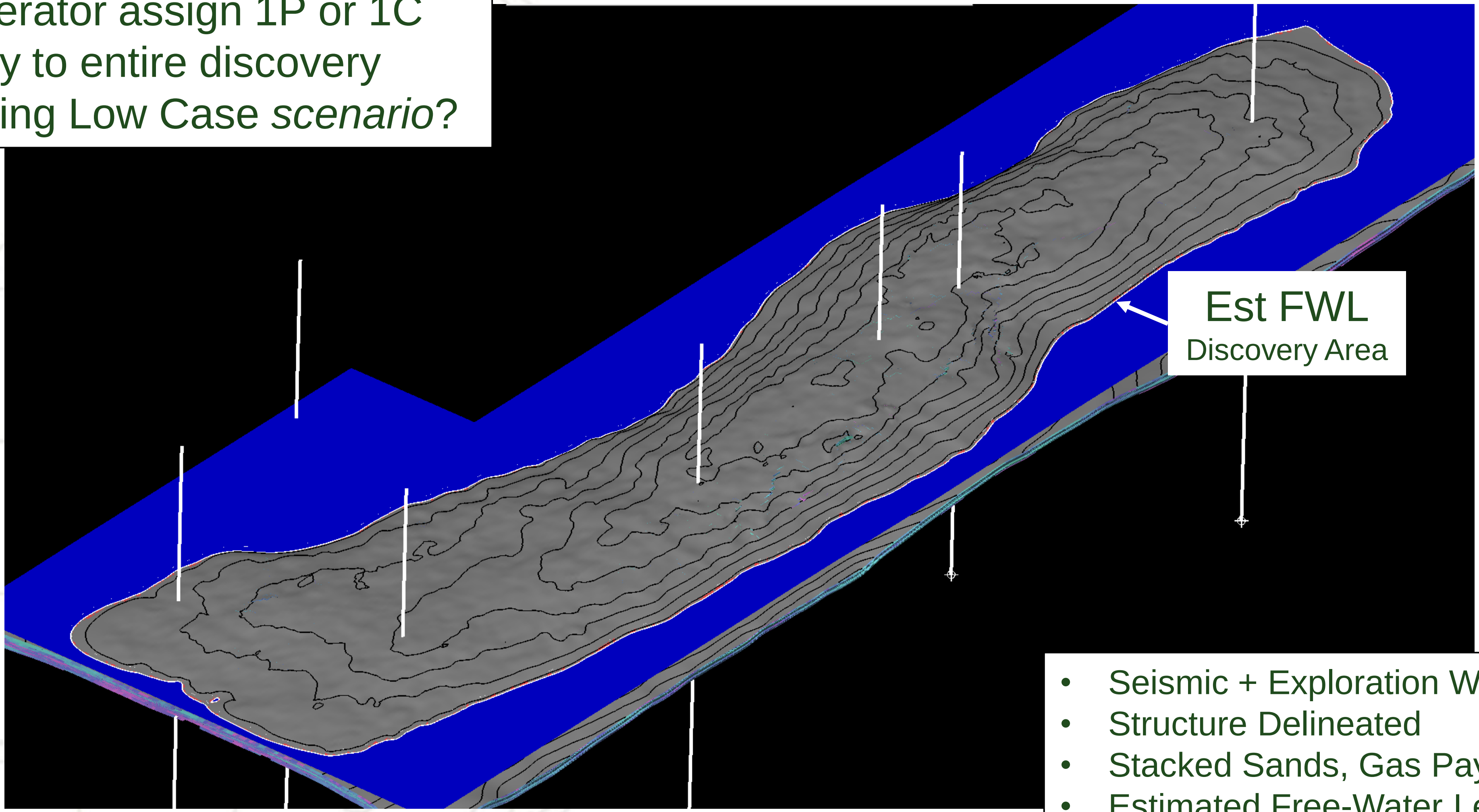




Is a “low case” model “proved” for the entire discovered area?

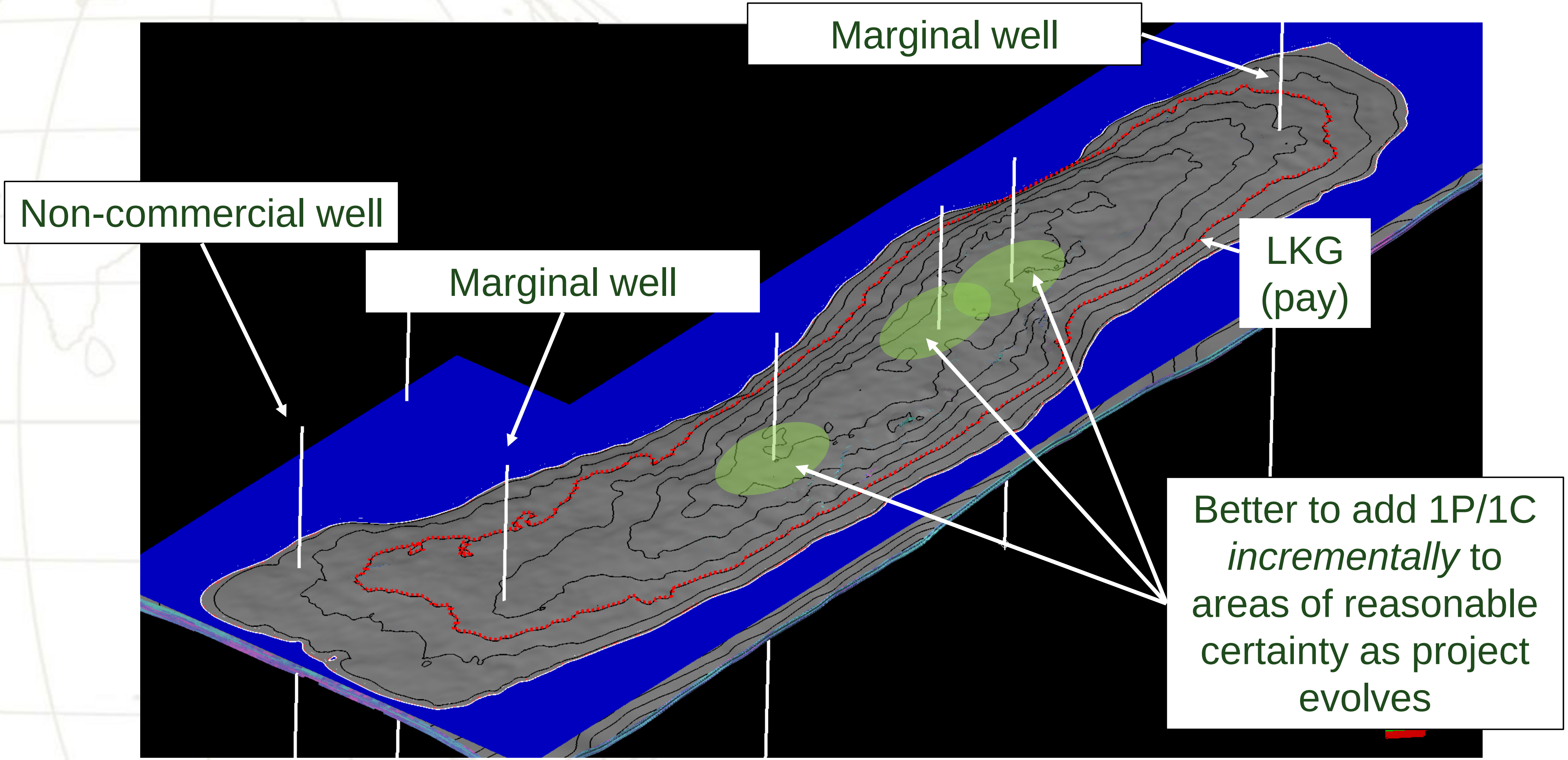
Key Volumetric Uncertainties

Can operator assign 1P or 1C category to entire discovery area using Low Case *scenario*?



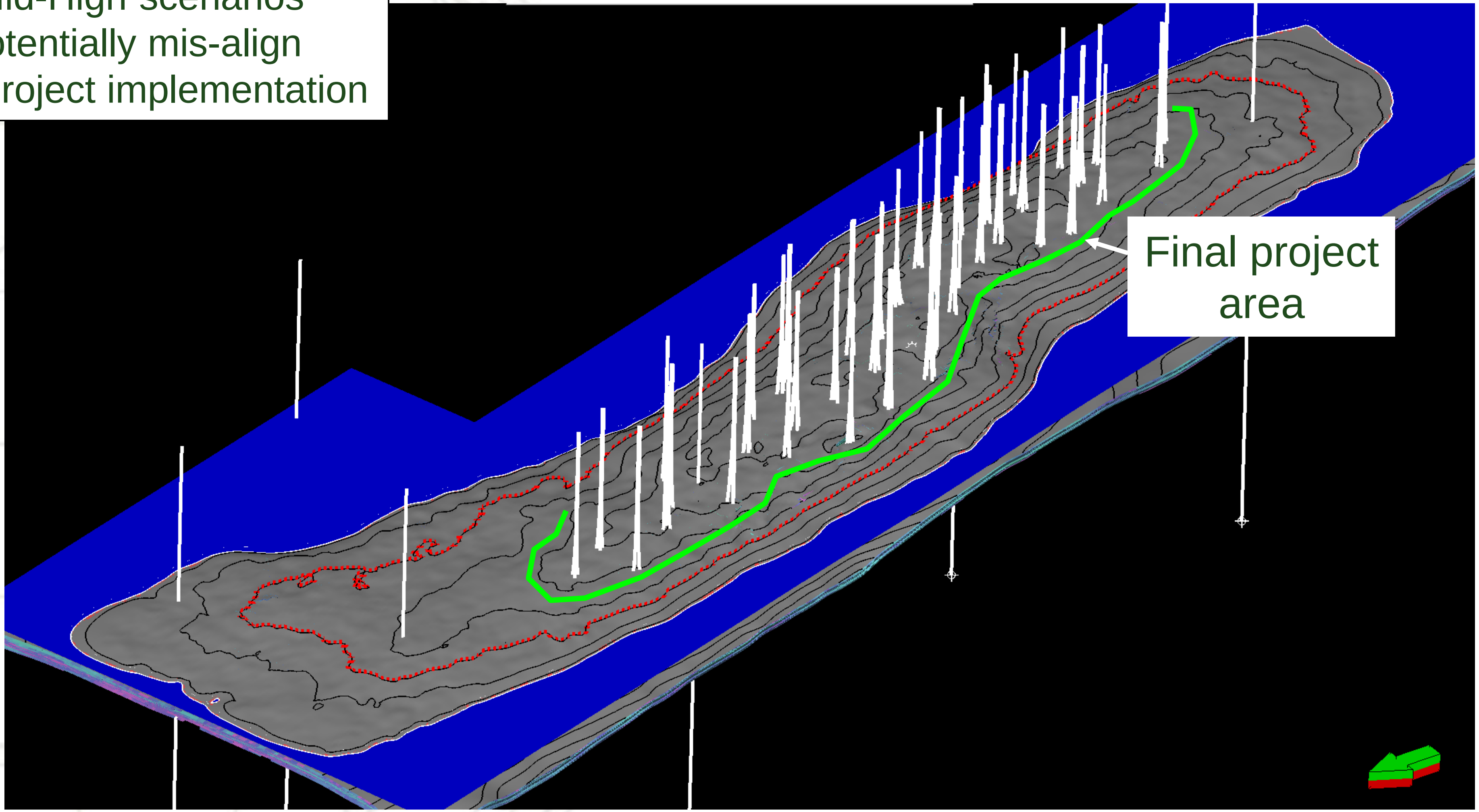
- Seismic + Exploration Wells
- Structure Delineated
- Stacked Sands, Gas Pay
- Estimated Free-Water Level

Key Volumetric Uncertainties



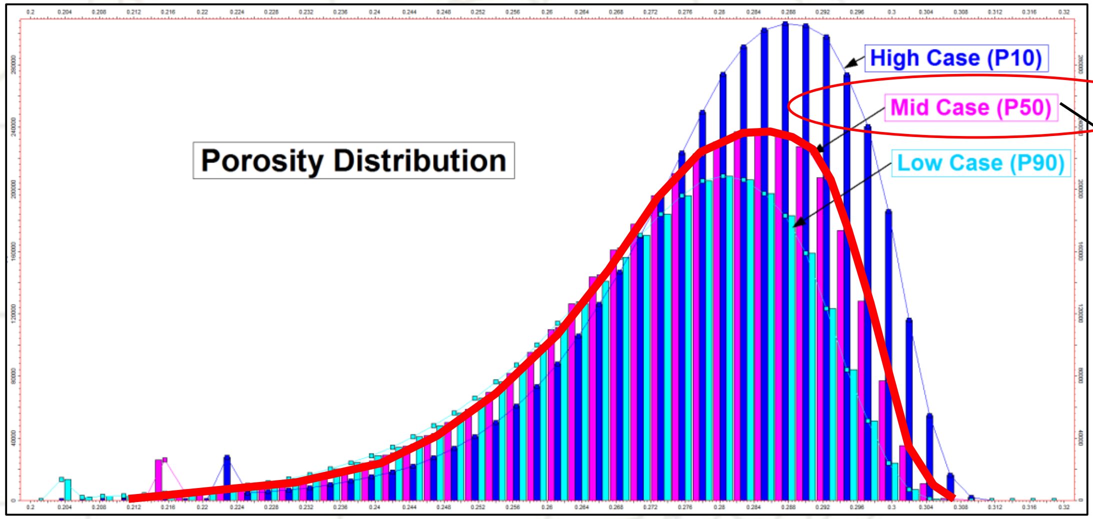
Key Volumetric Uncertainties

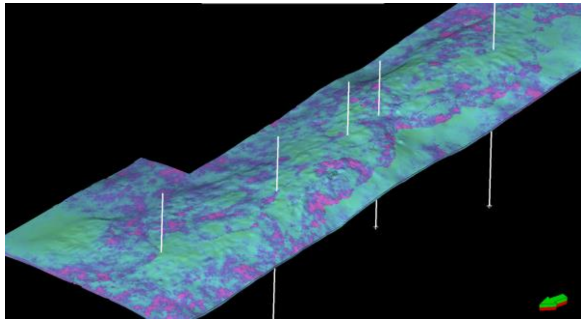
Low-Mid-High scenarios can potentially mis-align with project implementation



Recommendation

Use best-technical case model for all reserves categories.
Check conformance with data.





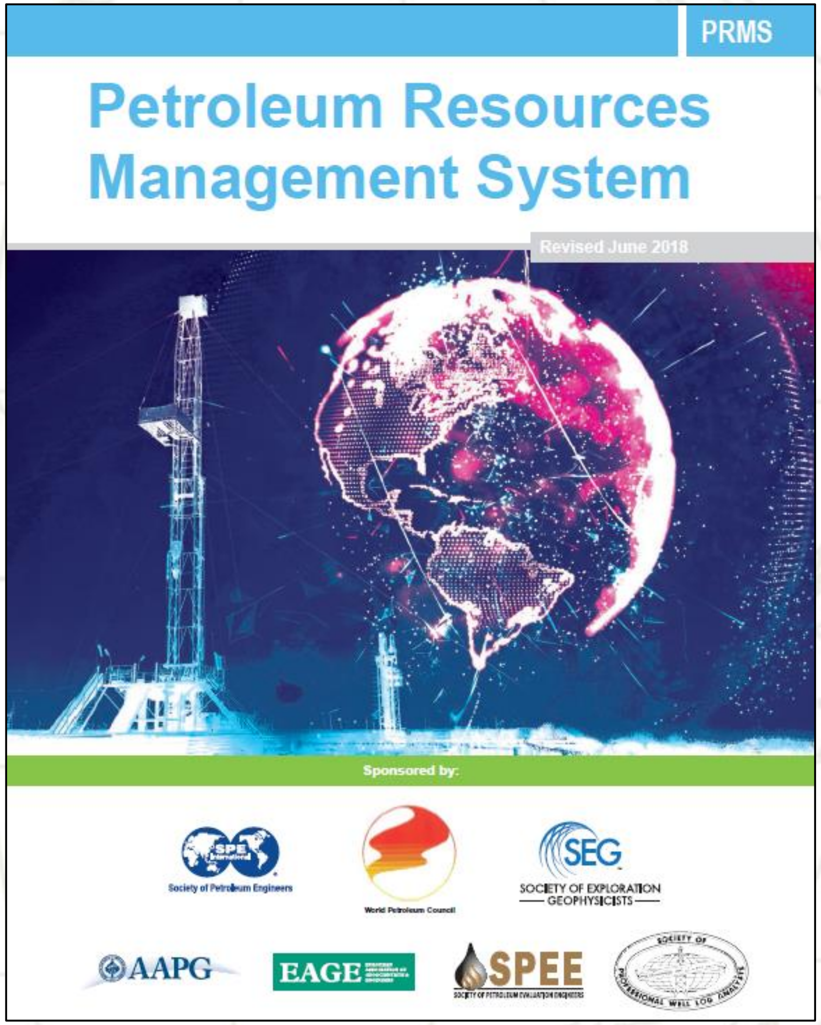
Apply appropriate contraints incrementally for compliance with definitions

Proved ≠ Pessimistic

Possible ≠ Optimistic

- Proved volumes = “reasonably certain”, not combined low-case assumptions.
- Probable and Possible volumes are not created by “stretching” the geology.
- 1P, 2P, 3P estimates rely on the same data and sound geological principles.
- Best-technical case models are generally most appropriate support of reserves volumes.
- Volume uncertainty managed by sound application of definitions (LKO, LKG, offset, barriers)

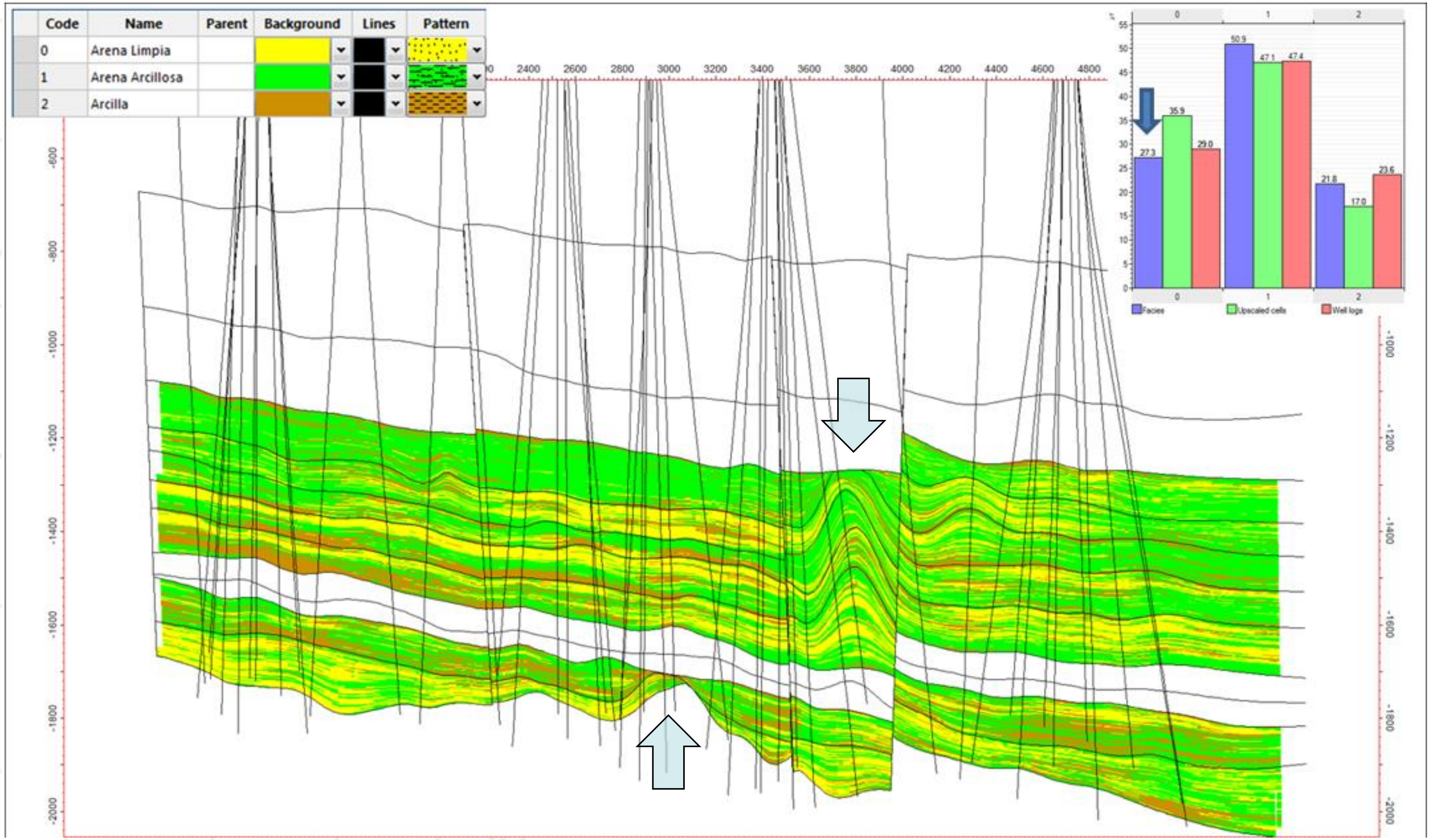
Words to the Wise



- Interpret(ation)(ed) – 13x
- Chance – 50x
- (un)Certain(ty)(ties) -119x
- Estimate(s) – 231x

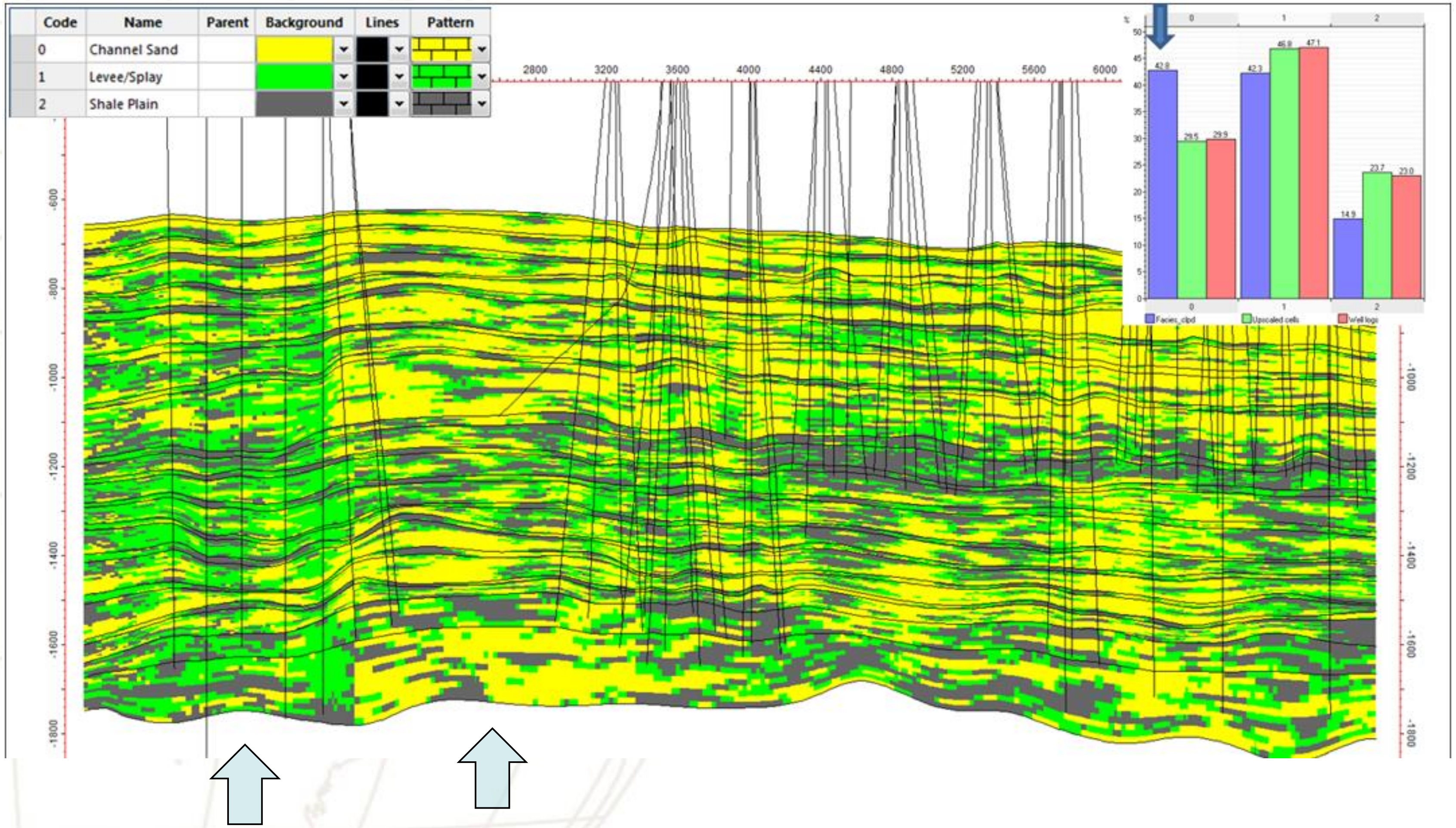
- (take) Care – 5x
- Consistent(ly) – 8x
- Reliable(ility) – 9x
- Confidence – 36x

Poor Control of Layering, Facies Proportions

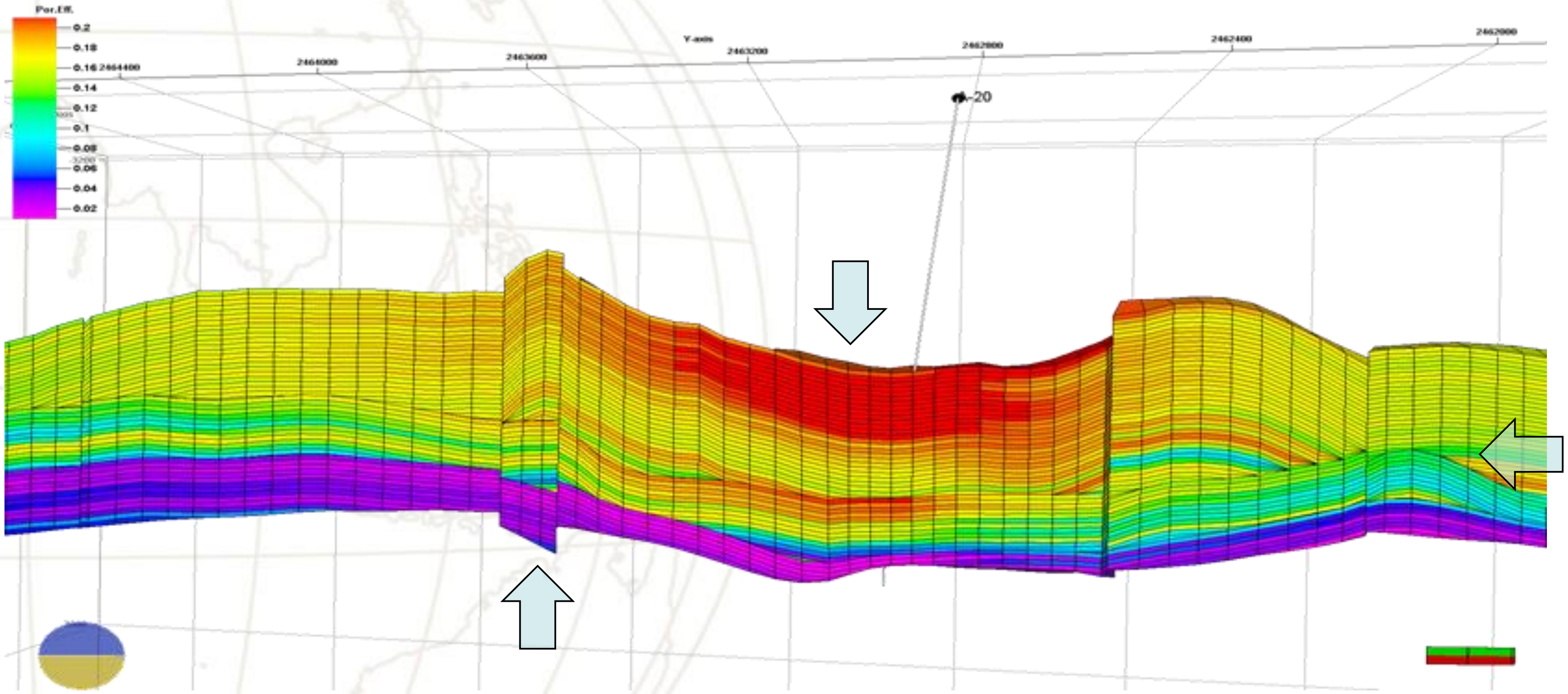


Facies – Inconsistent Distribution

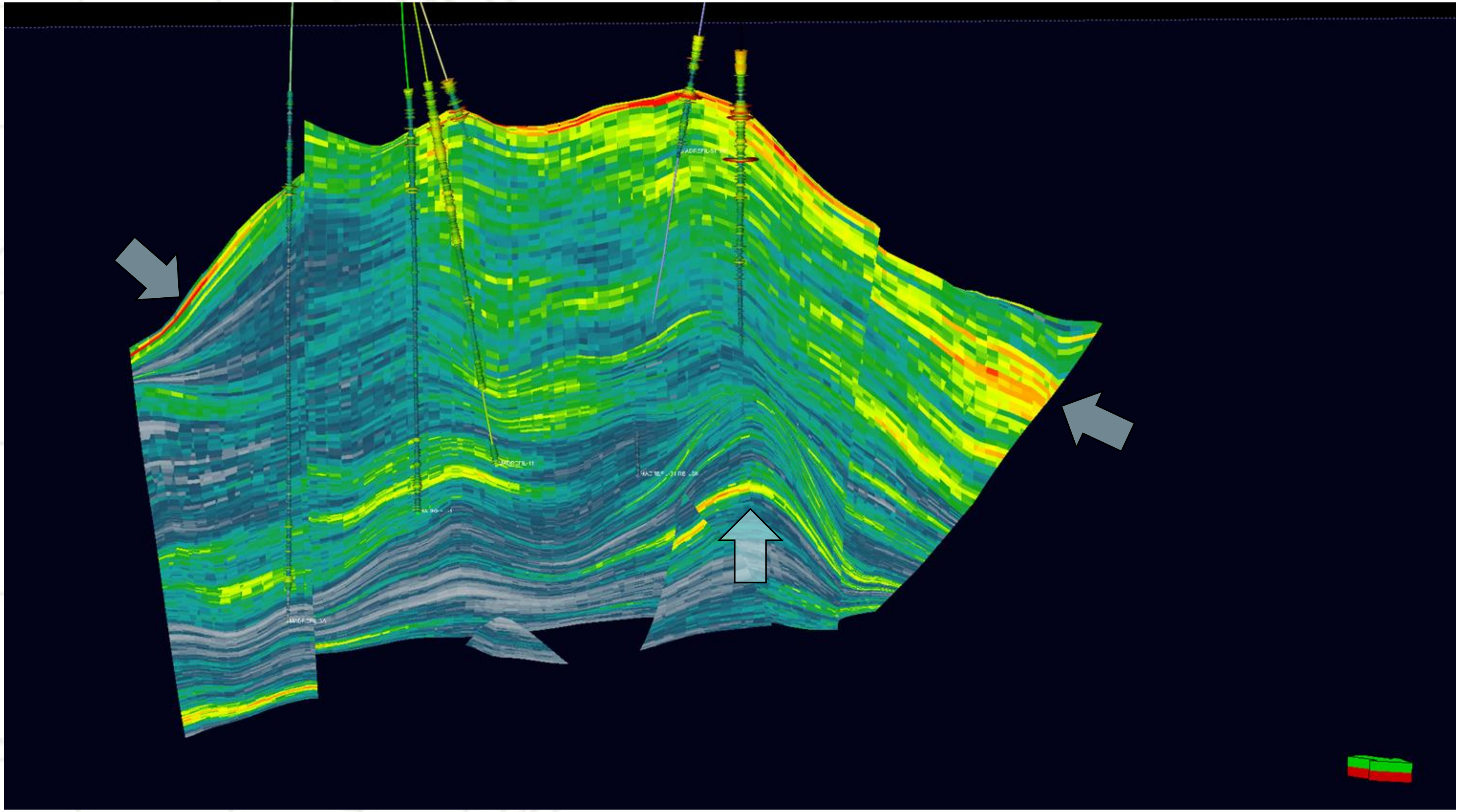
Code	Name	Parent	Background	Lines	Pattern
0	Channel Sand				
1	Levee/Splay				
2	Shale Plain				



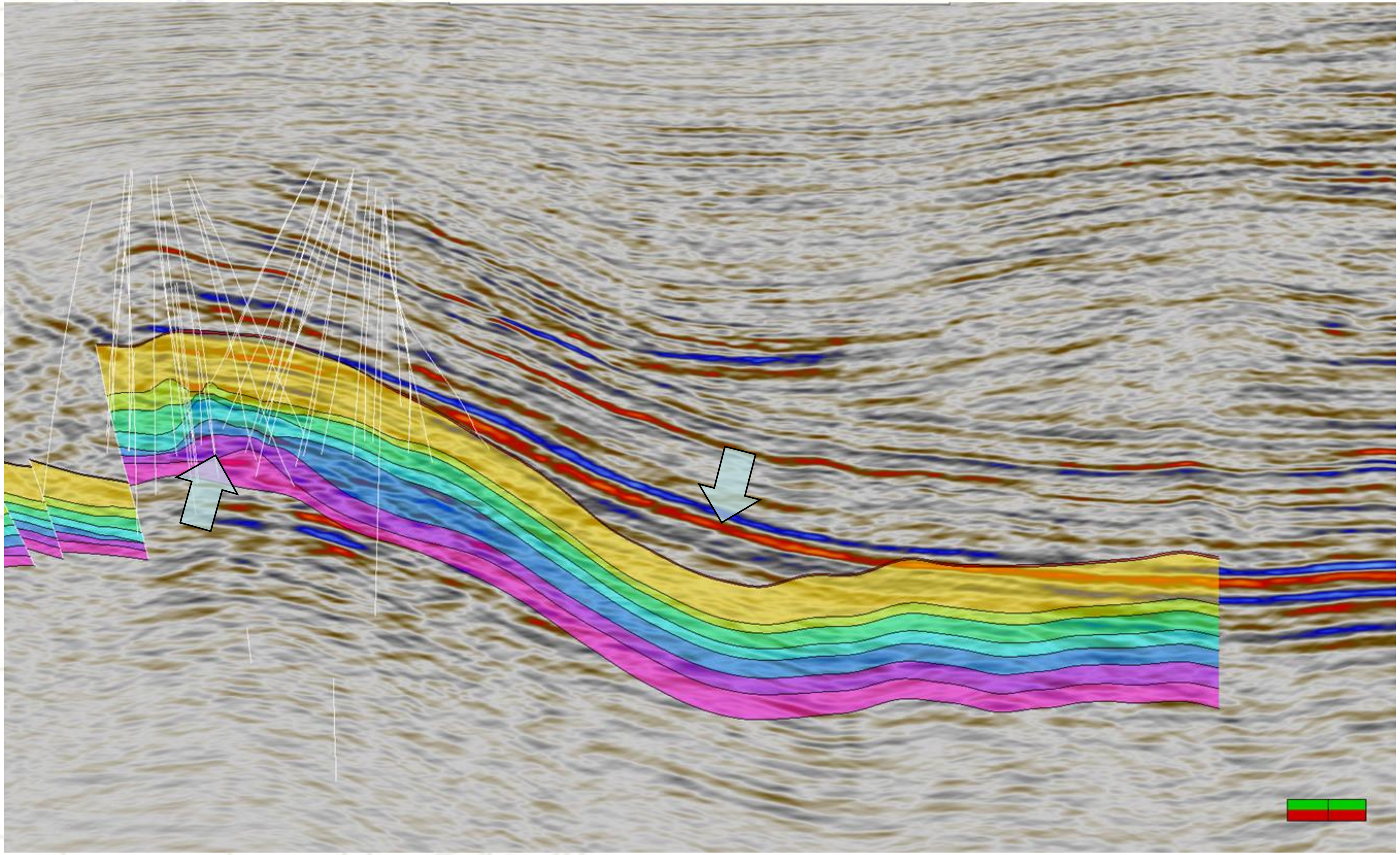
Structure, Faulting, Layering, Porosity



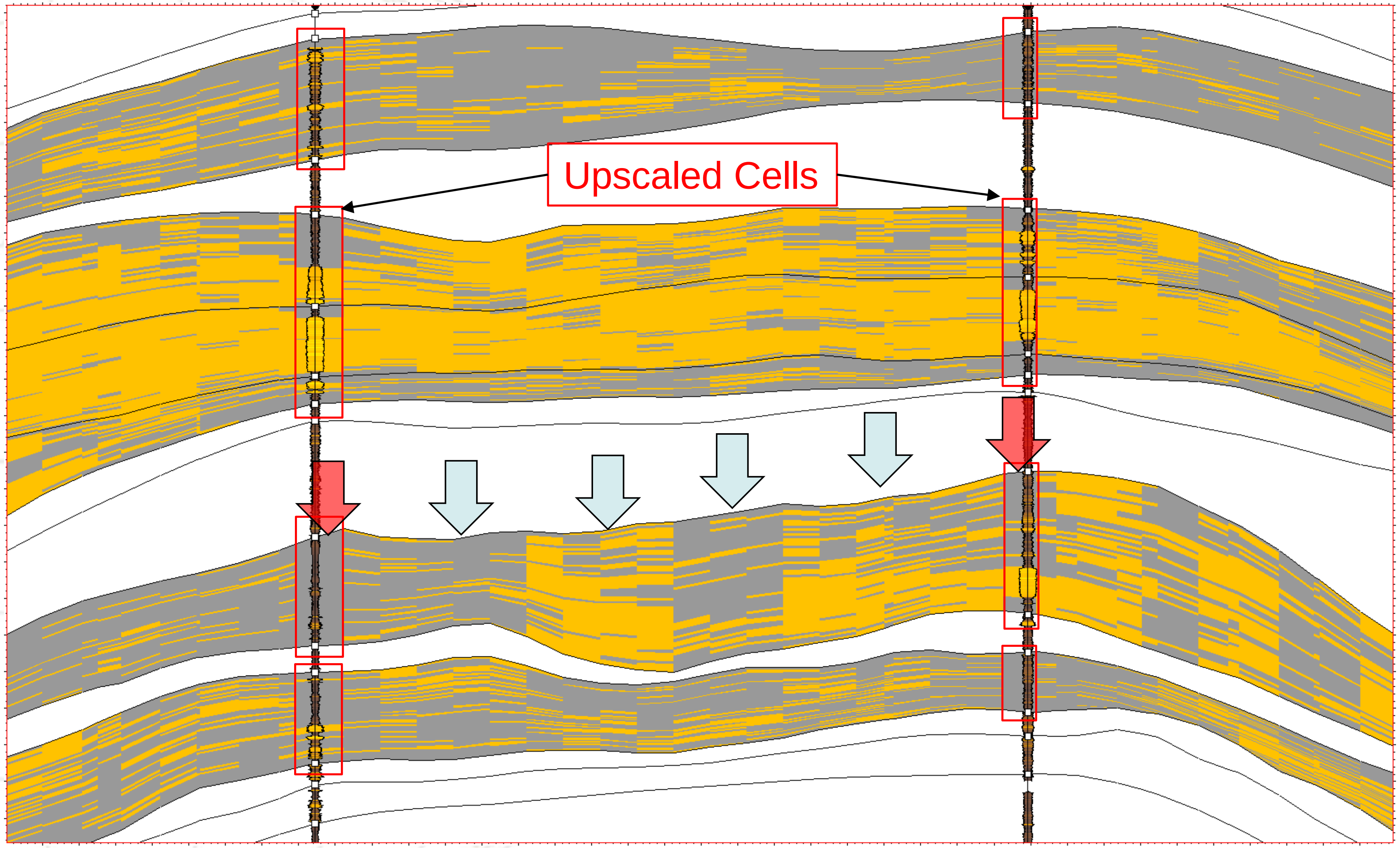
Structure, Layering, Porosity Model



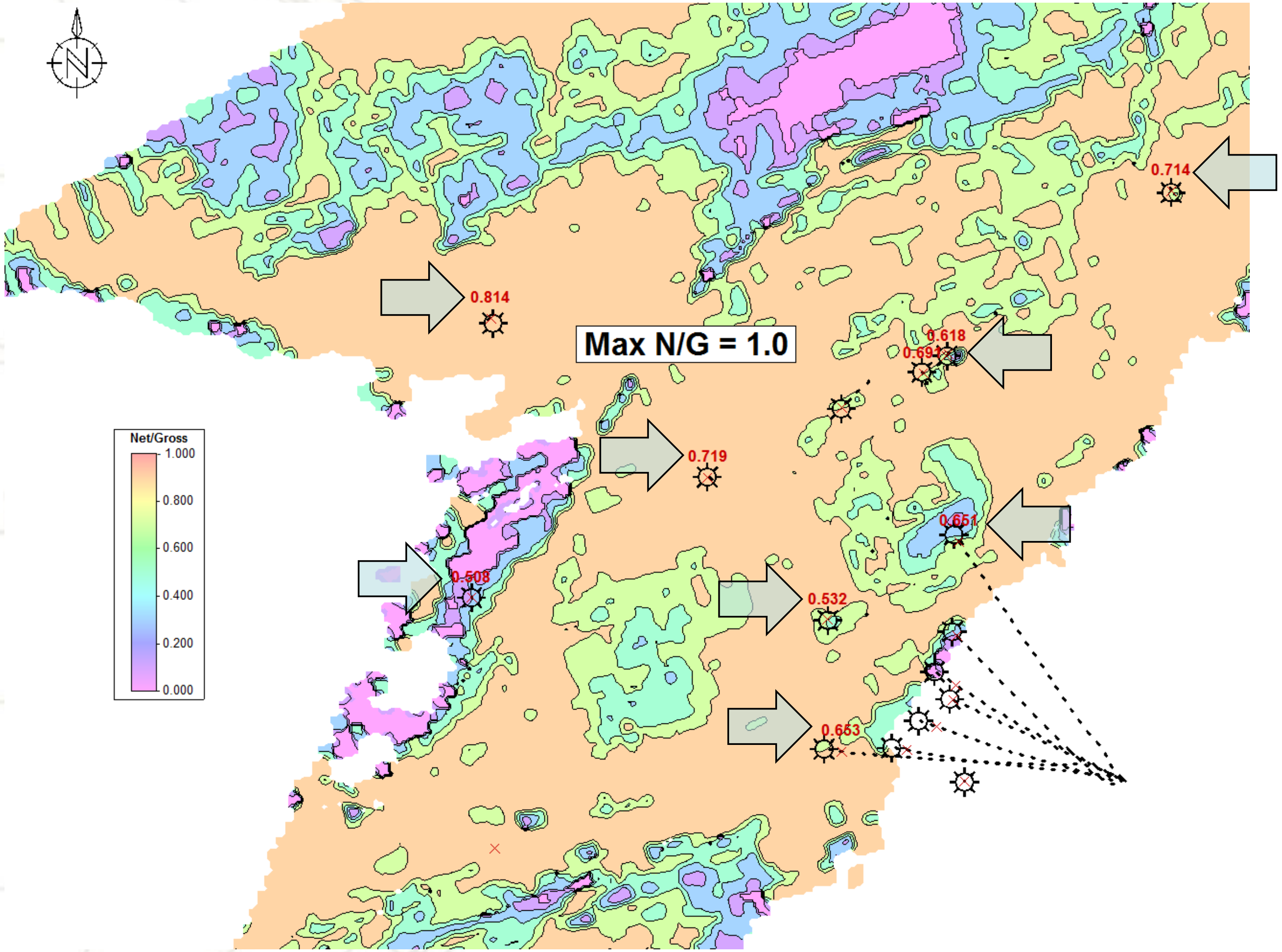
Structure, Layering Ignores Seismic



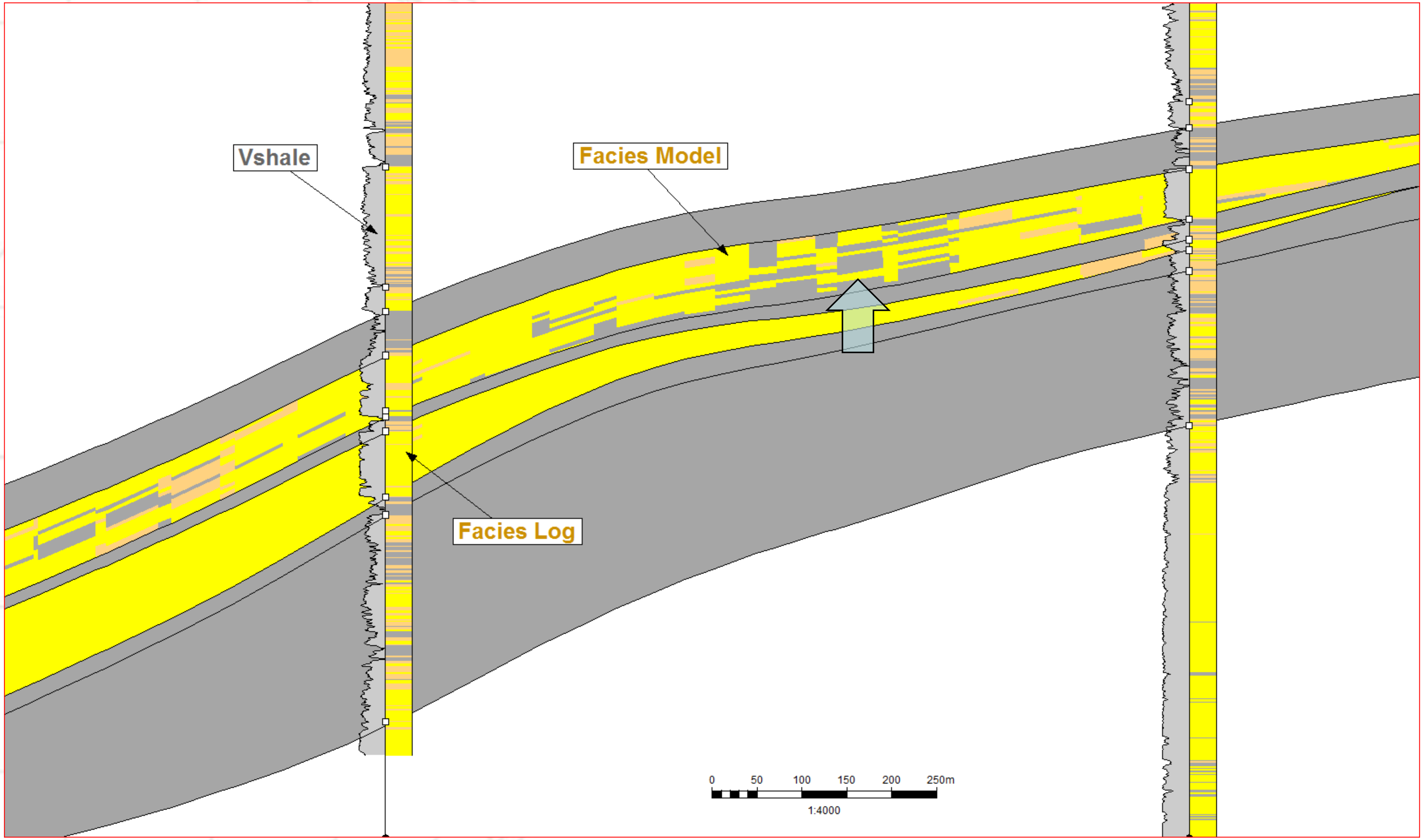
Net/Gross Exaggerated Between Wells



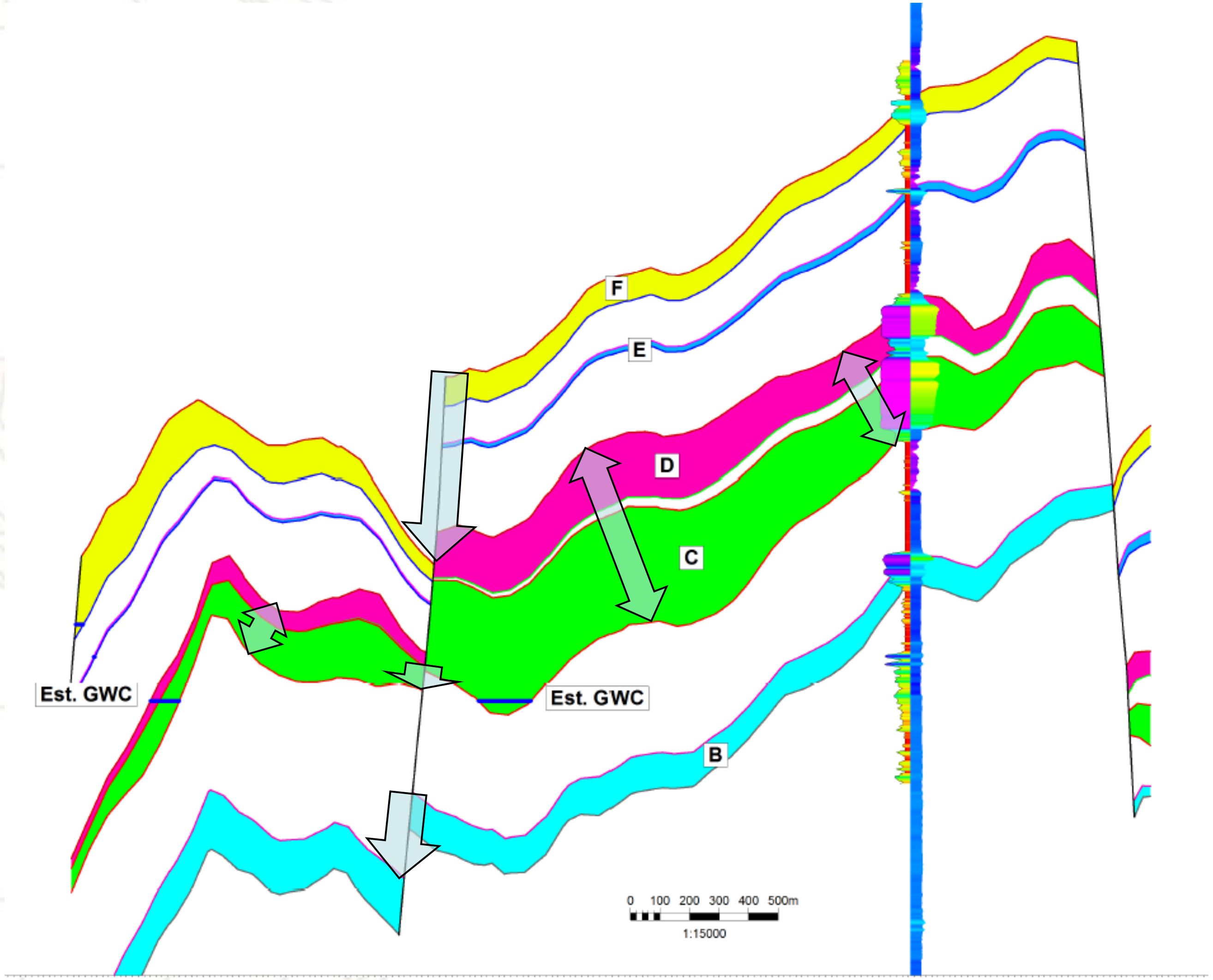
Net/Gross Exaggerated Between Wells



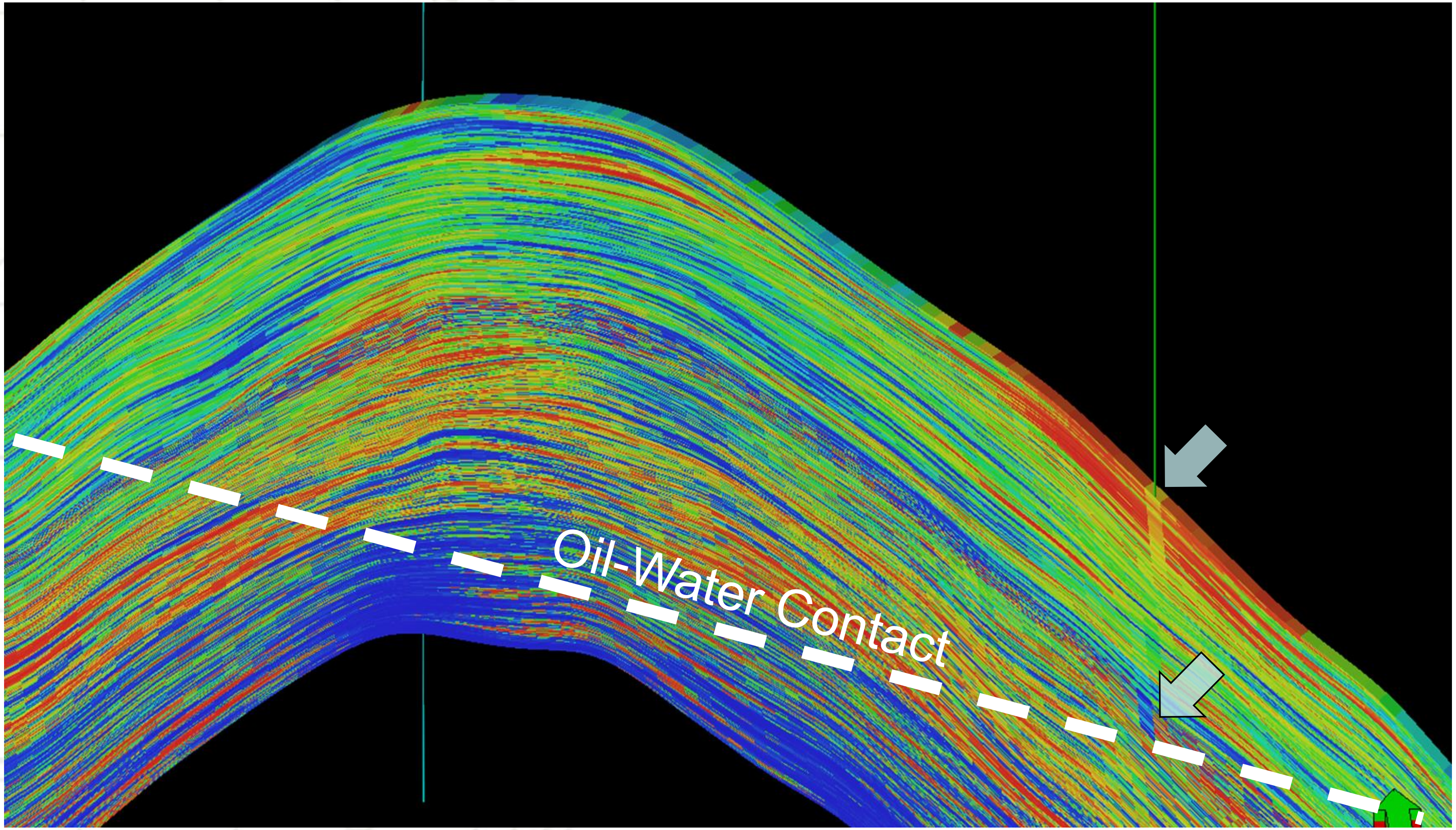
Facies – Incorrect Statistical Distribution



Structural Model – Faults, Thickness Not QC'd



Water Saturation Model – Incorrect Methods



Technology + Detail ≠ Quality

3D models that violate principles of petroleum geology reduce confidence in reserves estimations.

Stakeholders depend on your work, but most will never see it.

Today's Message

- Work with your eyes open