Reservoir Characterization and Modeling Strategies from Exploration through Development and Production Life-Cycle*

Taskin Akpulat[1]

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Abstract

Asset life cycle business strategy requires long-term planning from Exploration through Development and Production. The main objective in the Exploration phase is to discover new resources and attempt to quantify the uncertainty associated with those resources, while development and production focus more on cost effective strategies to recover the discovered resources. This paper demonstrates practical aspects of integrated reservoir characterization and modeling through the business life-cycle with examples from Anadarko Petroleum's deep-water portfolio. Integrated reservoir modeling is a multi-disciplinary effort with involvement from various functions working together to develop a set of reservoir models that are aligned to business needs. These needs are clearly defined and may change depending on the business life-cycle stage the field is going through (Exploration, Development, and Production) and the scale of the model that needs to be considered depending upon the business objectives (Basin, Field, Sector, and Wellbore). Technical, practical, and commercial variables need to be assessed prior to undertaking a reservoir evaluation study for adequate reservoir model design and timely execution. Reservoir characterization and modeling strategies outlined in this study can help asset teams in designing objective specific (fit-for-purpose) models to help answering business questions in a timely fashion.

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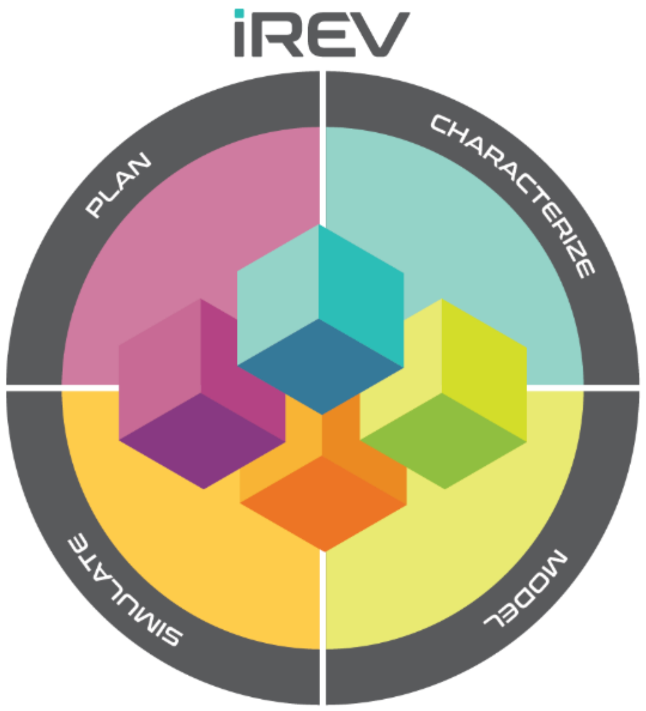
Reservoir Characterization and Modeling Strategies from Exploration through Development and Production Life-Cycle

Taskin Akpulat

30-Aug-2019

Objective and Agenda

- **Objective**
  - Reservoir characterization and modeling strategies for asset life-cycle
- **Agenda**
  - Introduction
  - Business Life-Cycle
    - *Exploration*
    - *Development*
    - *Production*
  - Reservoir Modeling Strategies
  - Conclusions



Exploration (EXP)

Resource Discovery
- Petroleum System
- 3D Seismic Acquisition
- Seismic Processing
- Core Description
- Depositional Analysis
- Well Pore Pressure Prediction
- Petrophysical Analysis
- Source Rock Geochemistry

Development (DEV)

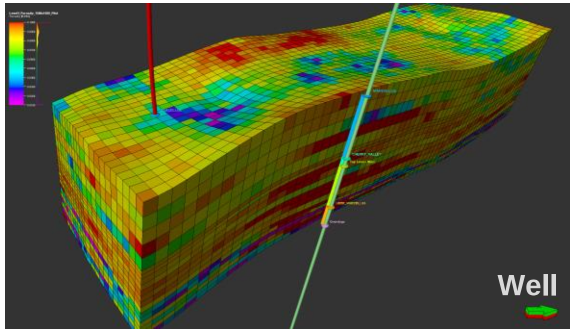
Field Development
- 3D Seismic
- Reprocessed Volumes
- Velocity Models
- Depositional Architecture
- Uncertainty Analysis
- Rock Property Petrophysics
- Geologic Model Building
- Reservoir Geochemistry

Production (PRD)

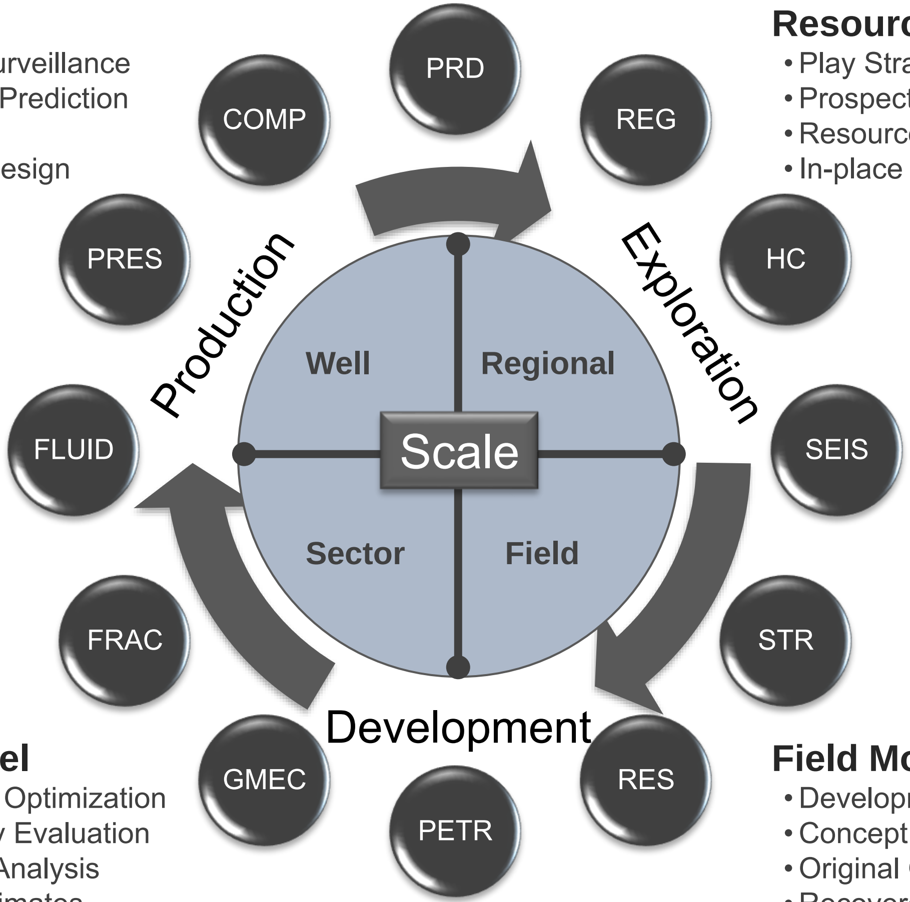
Reservoir Management
- Performance and Connectivity
- 4D Seismic
- PTA, RTA, Nodal Analysis,
- Material Balance
- Simulation
- Unswept Potential
- Artificial Lift
- Tie-In

Business Cycle

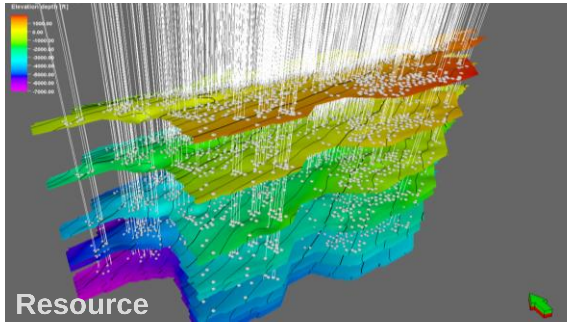
- Life-cycle modeling from Exploration through Development and Production
- Fit-for-purpose business life-cycle modeling at appropriate scale and for a well-defined objective(s)

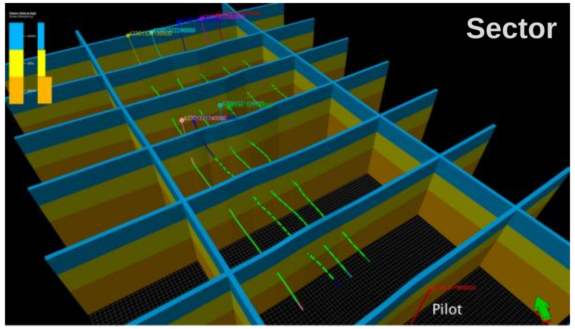


Well Model
- Production Surveillance
- Performance Prediction
- Well Spacing
- Completion Design



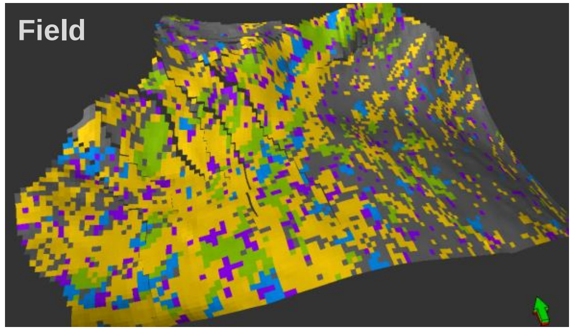
Resource Model
- Play Strategy
- Prospect Definition
- Resource Density
- In-place Uncertainty





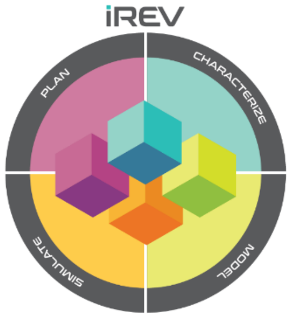
Sector Model
- Development Optimization
- Heterogeneity Evaluation
- Connectivity Analysis
- Reserves Estimates

Field Model
- Development Planning
- Concept Selection
- Original Oil/Gas in Place
- Recoverable Volumes

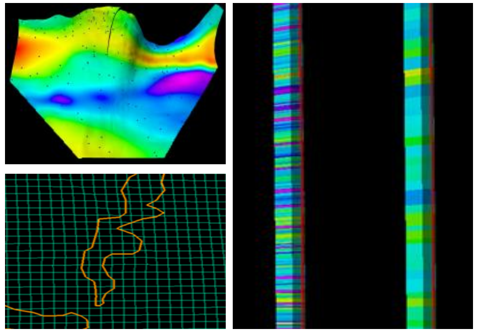


Reservoir Characterization & Modeling Strategies

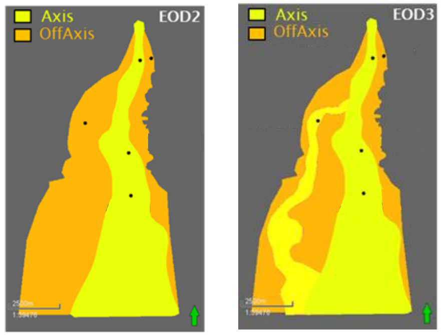
1 Define objectives, deliverables and timelines for successful planning and execution



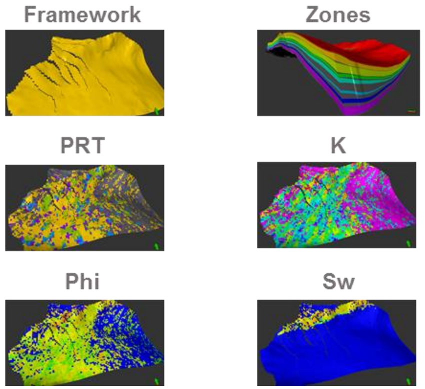
2 Investigate scale of representation for the problem defined



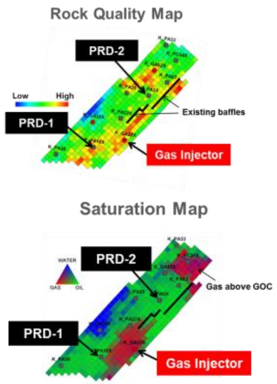
3 Identify critical flow elements that control reservoir performance



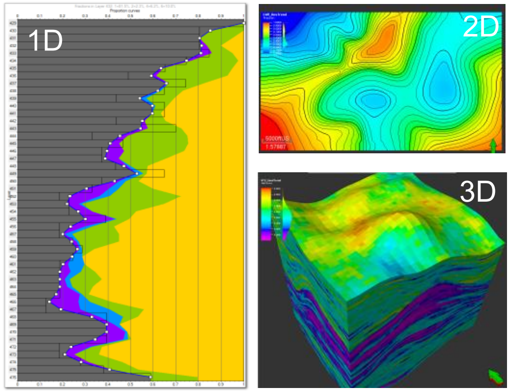
4 Design a reservoir modeling process that is simple, repeatable and easily updatable



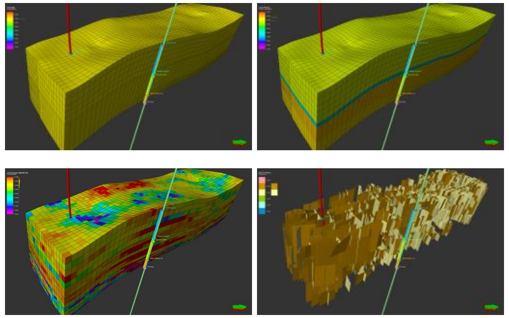
5 Represent multi-scale static and dynamic data properly at model scale



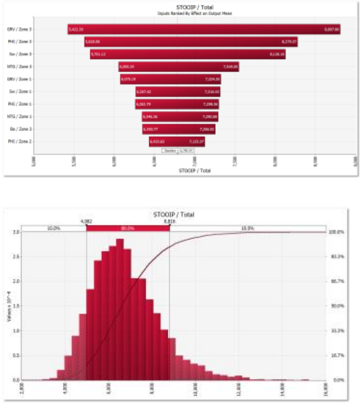
6 Honor available data and trends



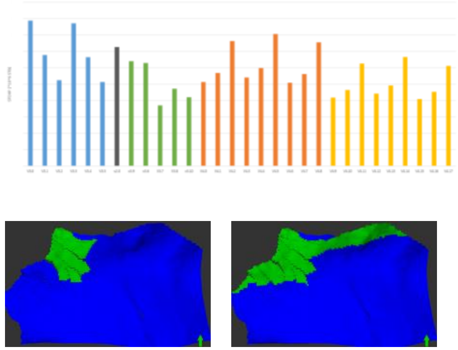
7 Start simple add complexity as needed



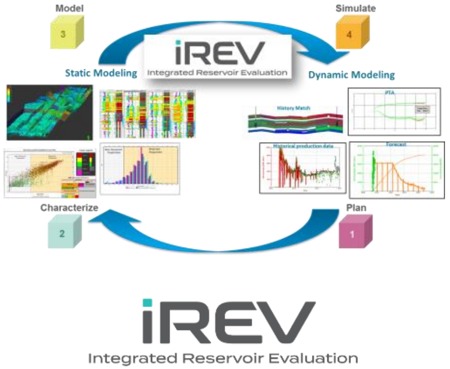
8 Quantify and model important uncertainties



9 Focus on commercial impact



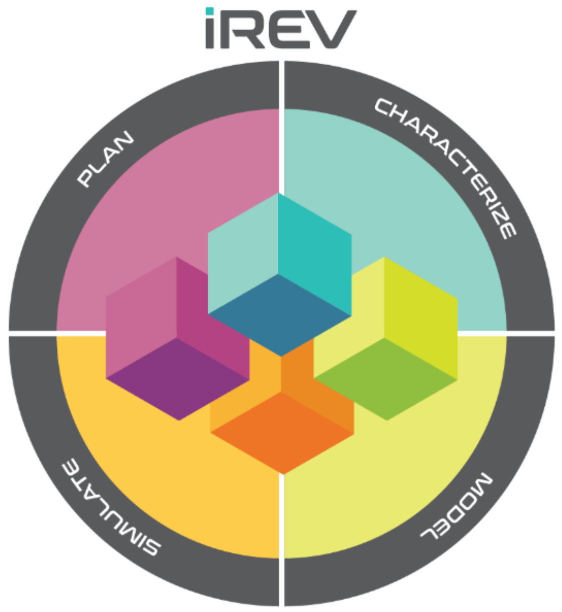
10 Incorporate simulation feedback

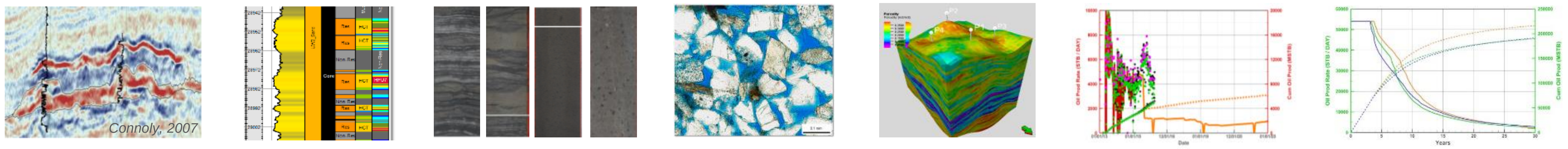


1. Define objectives, deliverables and timelines for successful planning and execution

- **Define clear objectives, people and timelines for successful planning and execution of the project from characterization, modeling and simulation. Integrated Reservoir Evaluation (iREV) is designed to help asset teams for planning and execution of major projects**

iREV
Integrated Reservoir Evaluation





iREV Reviews

Planning Review

Objective: Evaluate Characterization, Modeling and Simulation needs, resources and timelines

- Objective of Model
- Business Case
- Timelines
- Resources
- Reservoir Model Input Status
  - Framework
  - Reservoir
  - Facies
  - Porosity
  - Permeability
  - Sw
  - Volumetrics
  - Other
- Technical Readiness
- First pass QC of data

Characterization Review

Objective: Evaluate Characterization inputs for modeling technical readiness for the specified objectives

- Evaluate technical readiness and QC following elements for go-no-go decision
- Framework
  - Proper definition of container
- Reservoir
  - Definition, characterization and mapping evaluation of reservoir
- Facies
  - Consistent characterization of core, log and depositional model representation
- Phi-K-Sw
  - Petrophysical properties are adequately characterized consistent with core
- Project is ready to start modeling
  - If not, iterate on this until solution is reached before starting modeling

Modeling Review

Objective: Review model(s) and verify that multiple scenarios are constructed to mitigate uncertainties as characterized

- Integrated Model Review of reservoir Elements as characterized
- Framework
  - Proper definition of container in depth
- Reservoir
  - Adequate scale and model representation (1D,2D,3D)
- Facies
  - Consistent modeling of facies with depositional model and trend data
- Phi-K-Sw
  - Petrophysical properties are consistently modeled as described
- Volumetric comparison of BTE to previous estimate
- QC entire model
  - Simulate and plan for uncertainty

Simulation Review

Objective: Review simulation model(s) and its elements and verify that it adequately represents reservoir model(s)

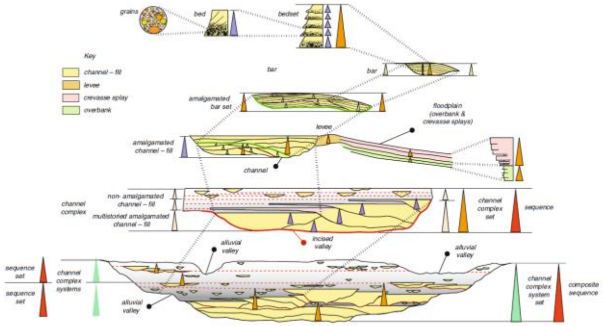
- Verify upscaling if not common scale
- Verify that RM and SM has same STOOIP or GIIIP
- Connectivity Analysis
- P&T
- Relative Permeability
- Contacts
- Aquifer Volume
- Review scenarios for pre-development
- Review sensitivity analysis
- Resources
- History Data
- Review HM parameters and basis
- Evaluate HM Quality
  - Per Well
  - Per Segment
  - Per Field

2. Investigate scale of representation for the problem defined

- **Investigate dominant scale controlling fluid flow and represent it in the model. Important heterogeneities might be structural, stratigraphic or any other (e.g. diagenetic). Multi-functional teams needed to define what matters to flow**

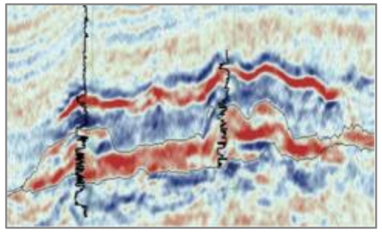
Field

Clastic Systems Architecture Elements



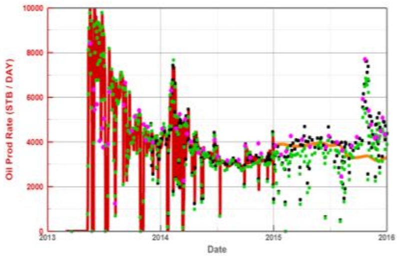
C. Kendall 2014 after Sprague et al., 2002, and Catuneanu, et al, 2011

Seismic

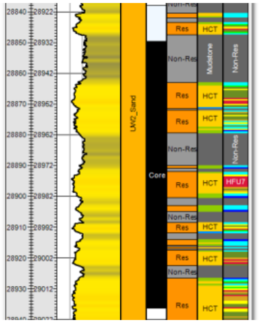


Connoly, 2007

Production



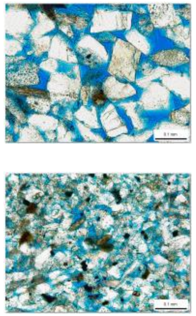
Log



Core

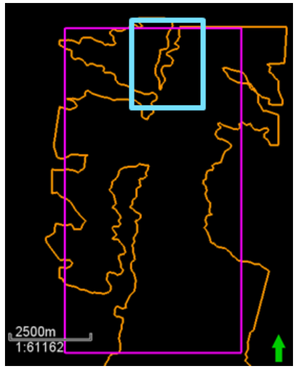
HCT LCT VLCT SD M

Pore

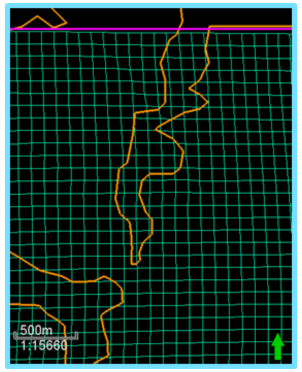


Areal (2D) Representation

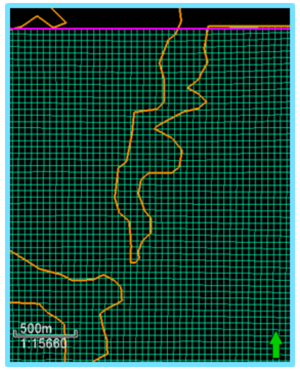
Channel Element



Coarse

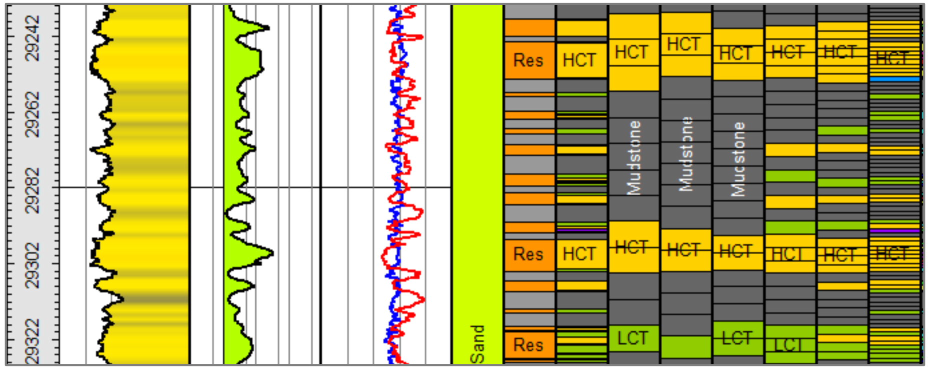


Fine



Vertical (1D) Representation

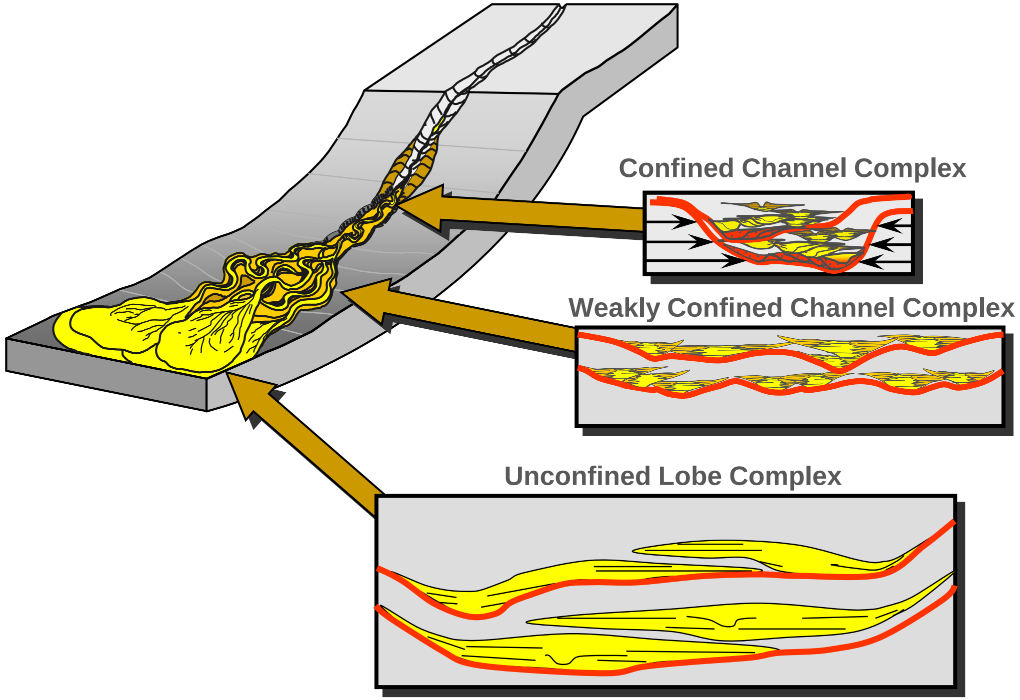
Coarse → Fine



3. Identify critical flow elements that control the reservoir performance

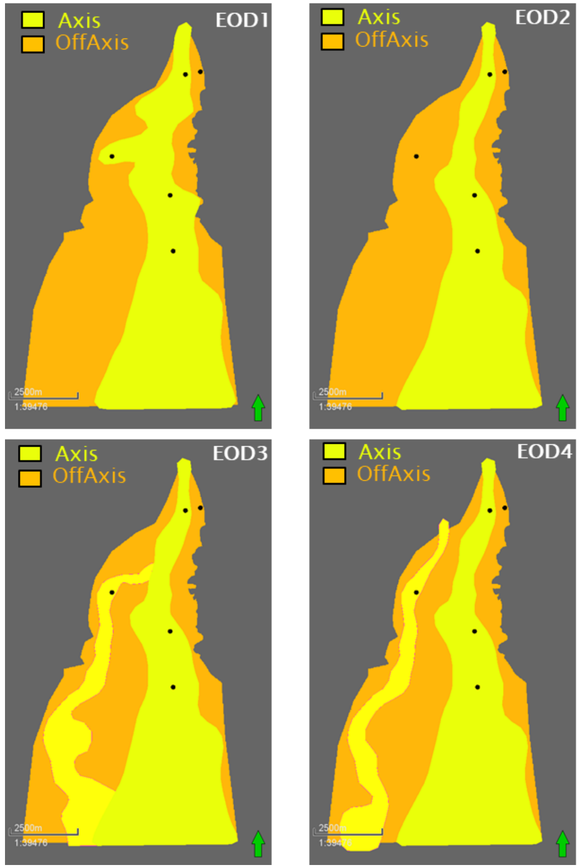
- Study reservoir performance to identify key critical elements that control fluid flow and construct simple models to quantify the response

Stratigraphic Architecture

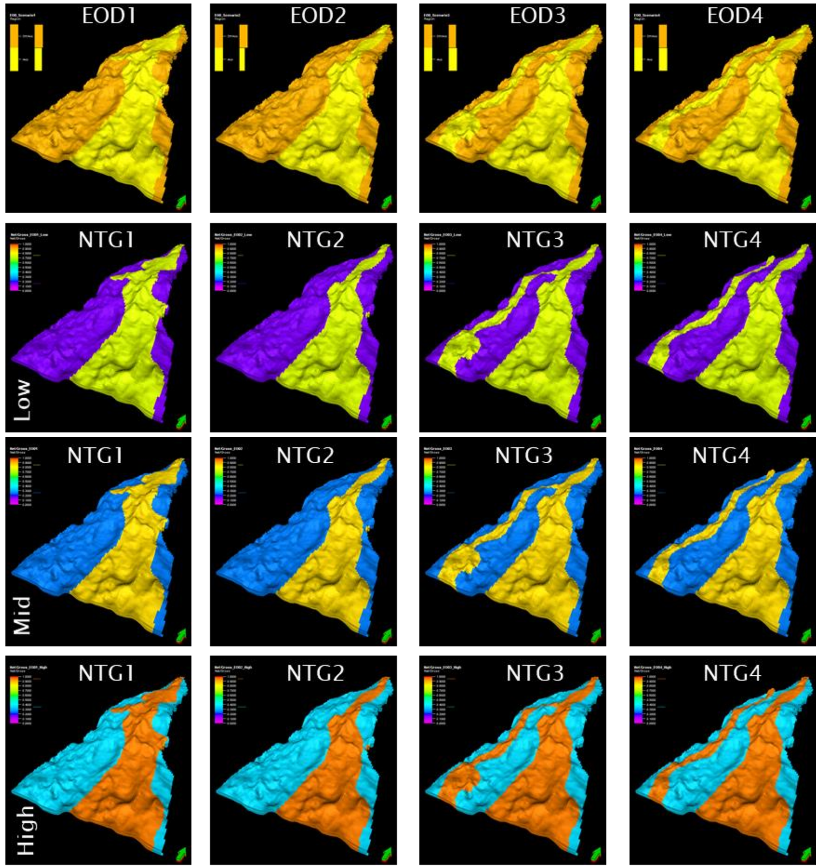


Porter, M.L., et al (2006)

EOD Scenarios



Conceptual Models



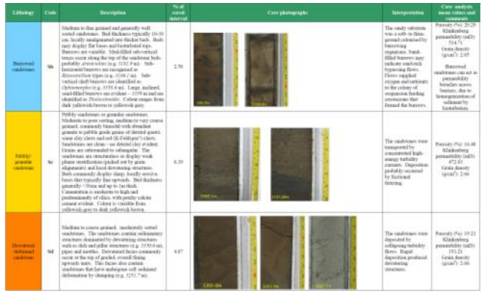
Critical Flow Elements Examples:
Stratigraphic architecture, environment of deposition (EOD), channel stacking patterns, high-perm streaks, diagenesis, fractures, faults, aquifer size, axis-margin connectivity, relative perm, pressure distribution.

4. Design a reservoir modeling process that is simple, repeatable and easily updatable

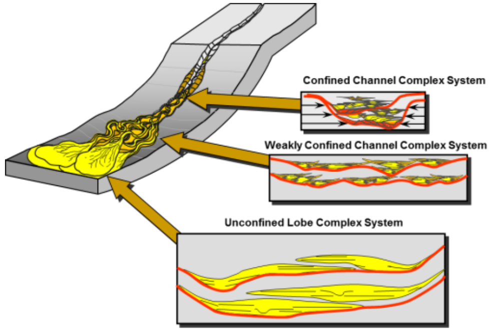
- **Construct multiple deterministic models addressing specific business problems using a simple, repeatable and easily updatable workflow so that as new data becomes available it can be quickly incorporated into model(s)**

Core Description

Lithofacies Identification



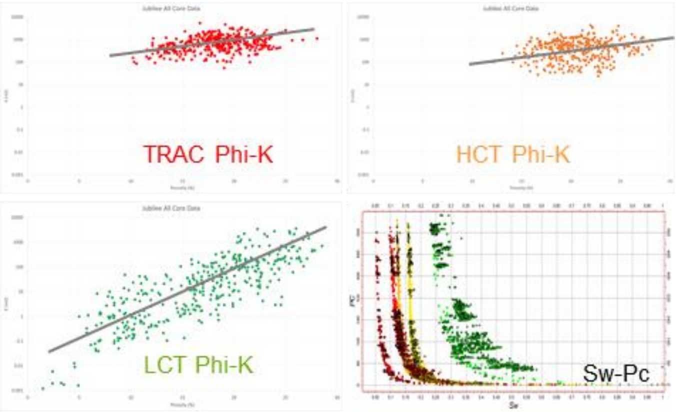
Depositional Concept



Porter, M.L., et al (2006)

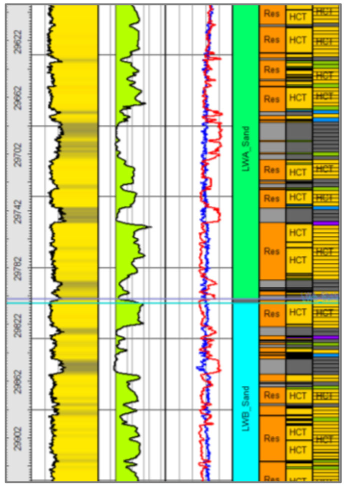
Reservoir Rock Types (RRT)

Core Properties by RRT

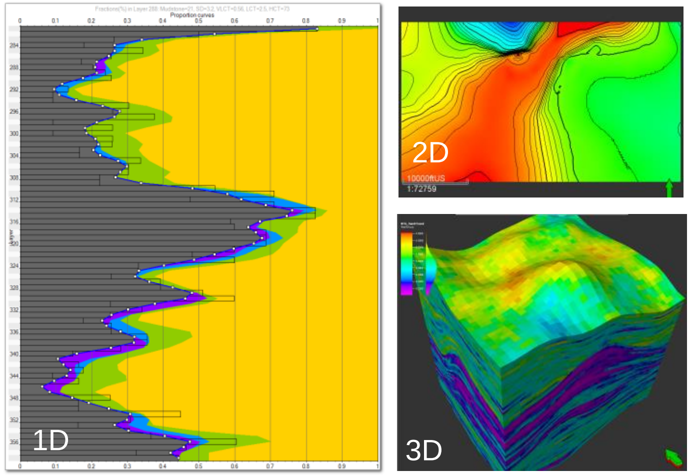


Reservoir properties and functions by RRT (Phi-K and Sw-Pc) from core data

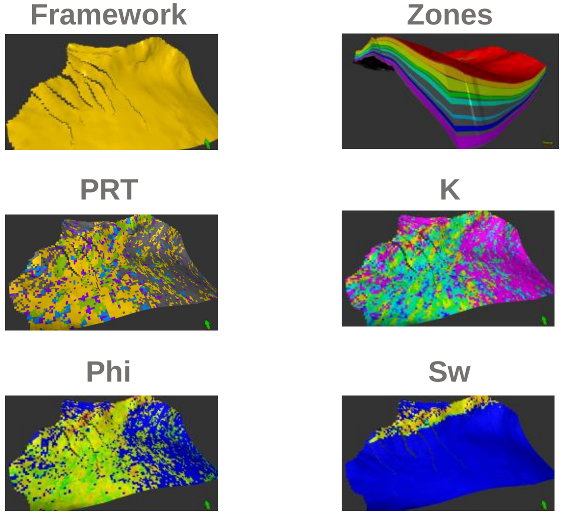
Petrophysical Rock Types (PRT)



Property Conditioning



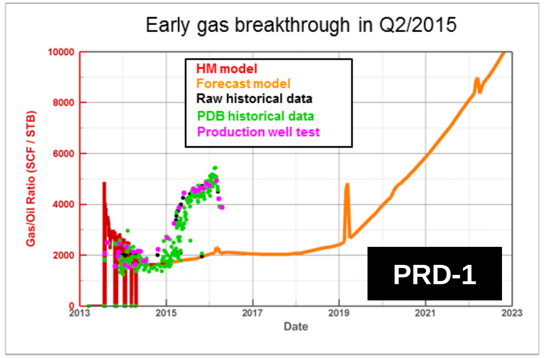
Reservoir Model



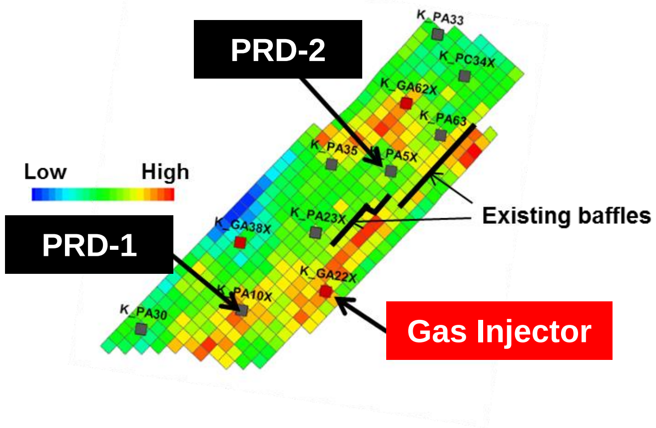
5. Represent multi-scale static and dynamic data properly at model scale

- Integrate static (core-log-seismic) data as much as dynamic data (well test-production) along with geologic concept for better prediction. Analysis of production data can give us good insight into geology and critical flow elements and should be incorporated into model

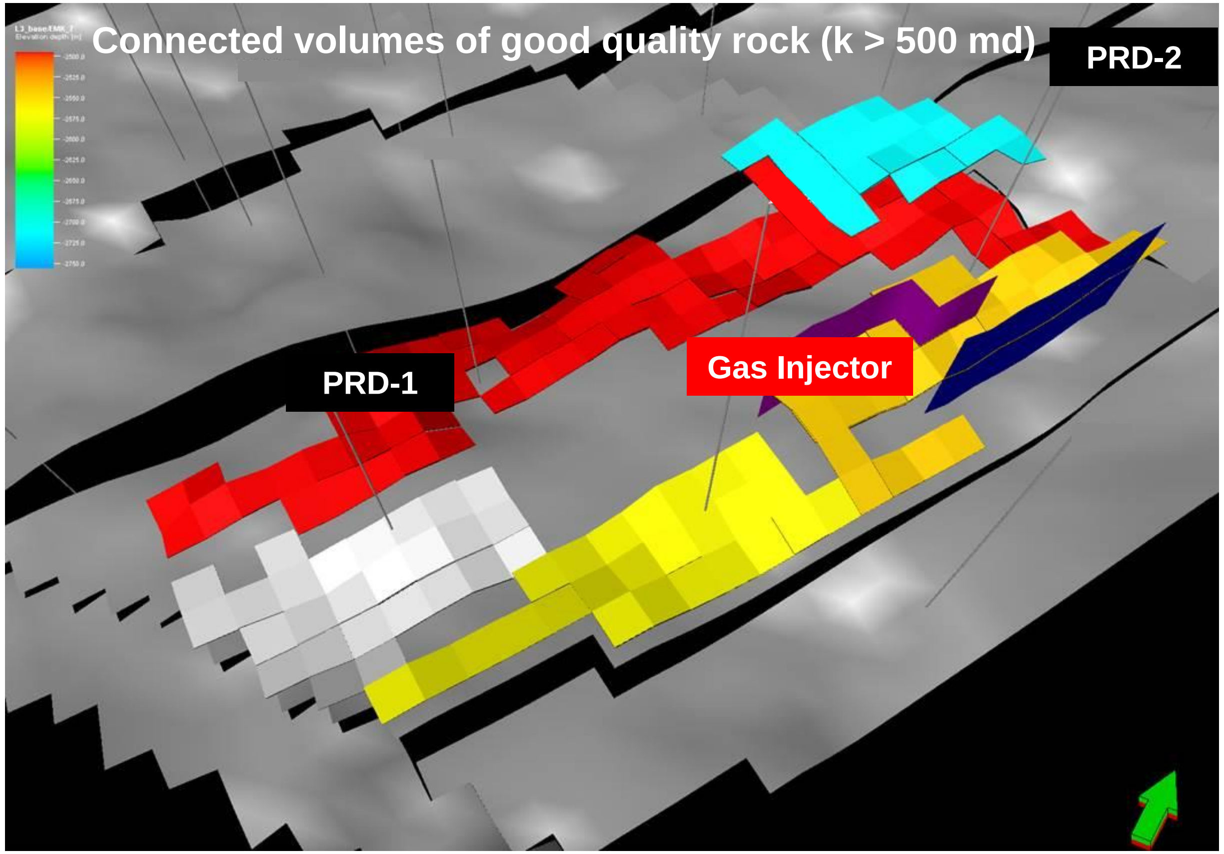
Production Performance



Rock Quality Map

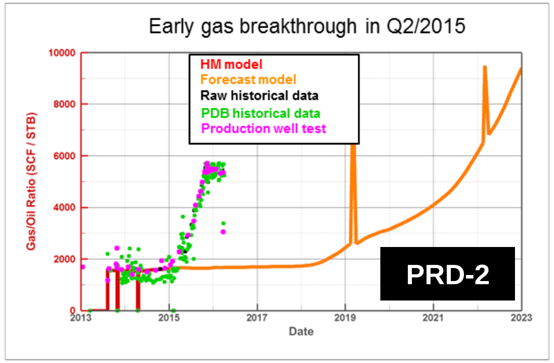


Model Static Connectivity Analysis

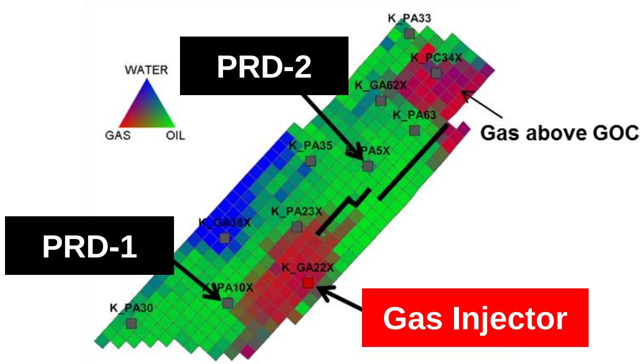


Limited connectivity between Gas Injector and Producers

Production Performance



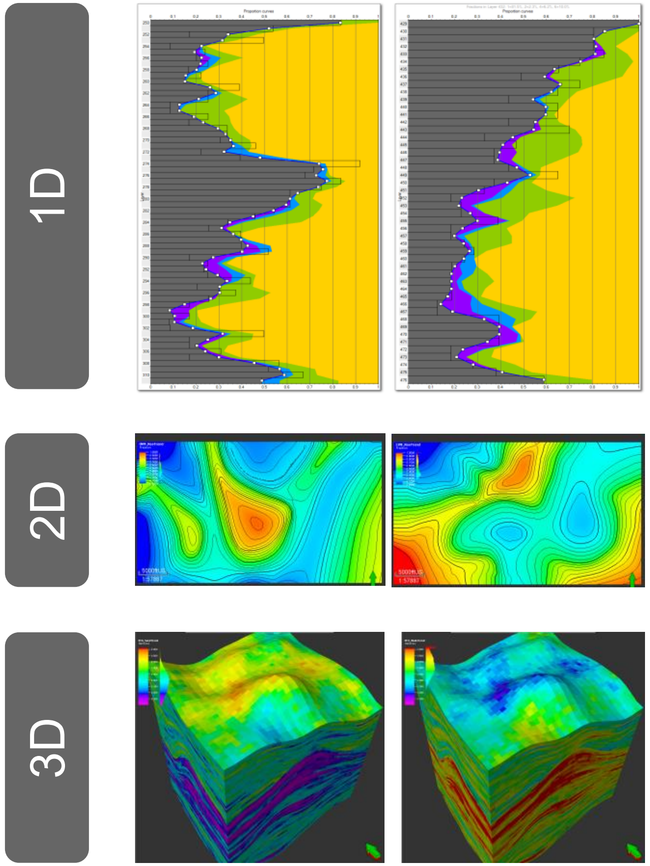
Saturation Map



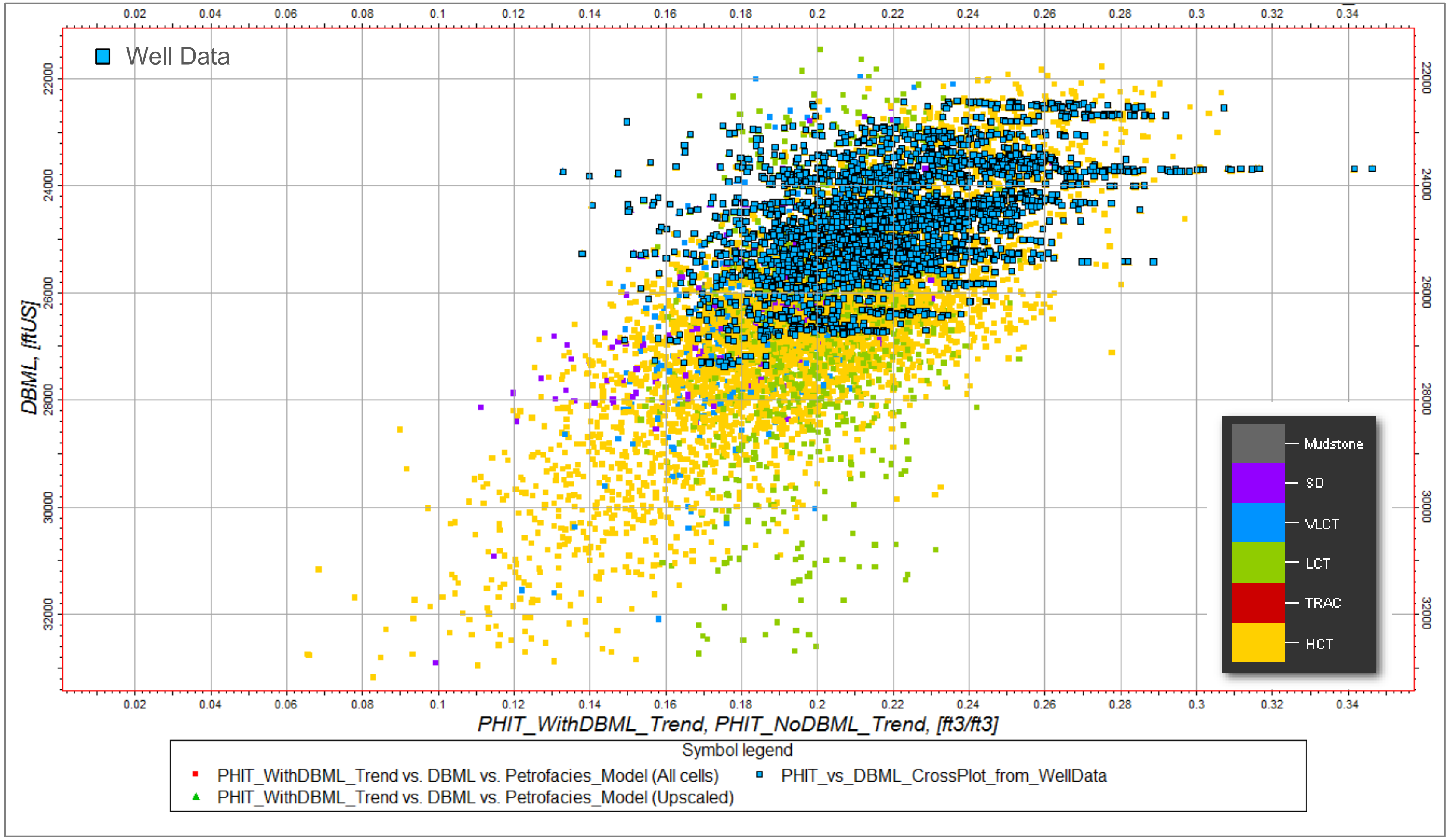
6. Honor Available Data and Trends

- Use conceptual and geological trends observed in the field. Utilize both static and dynamic data conditioning where applicable

Trends



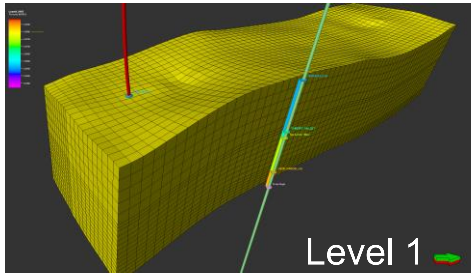
Porosity with DBML Trend

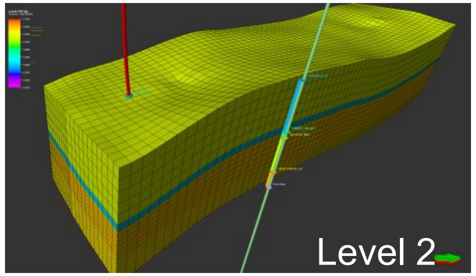


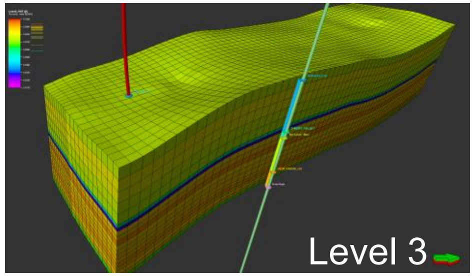
7. Start simple add complexity as needed

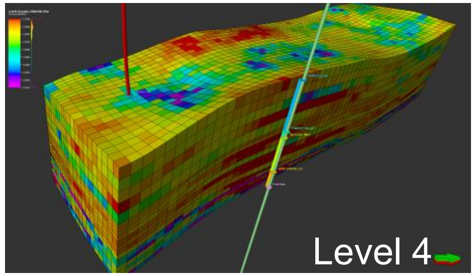
- **Design simple deterministic models to study problem(s). Increase complexity as needed. Highly complex models tend to take more time to construct and commonly does not provide additional insights for business decisions**

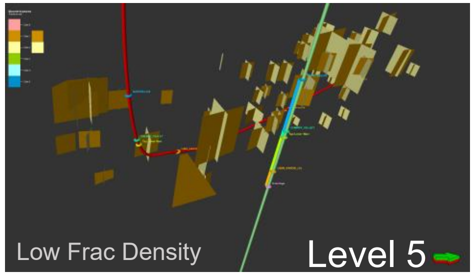
US Onshore

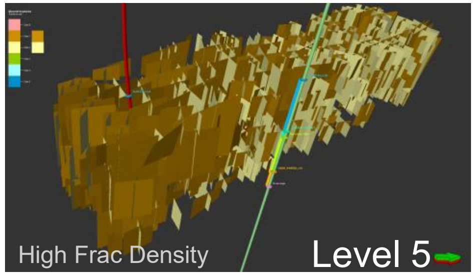


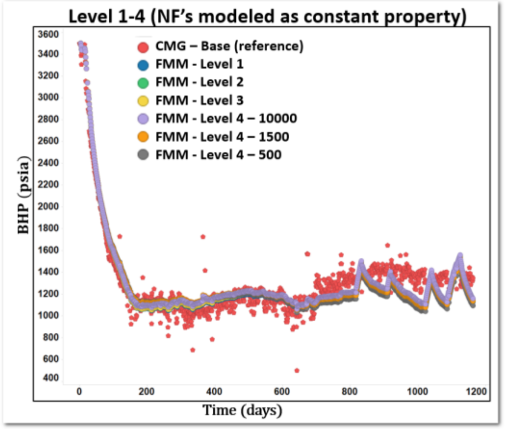


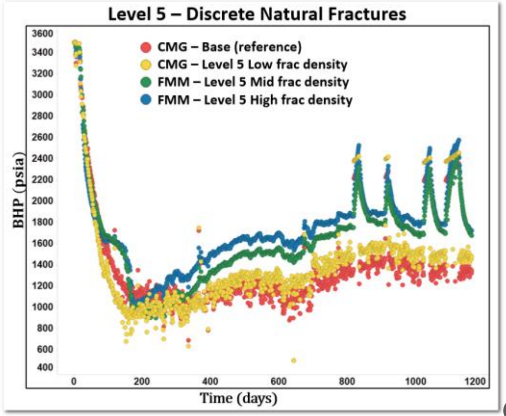






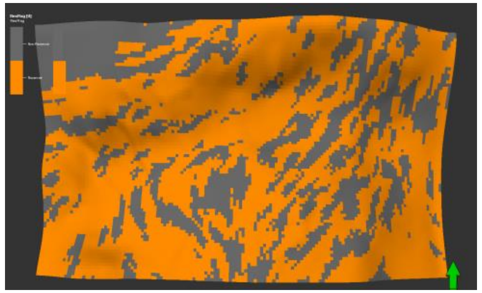






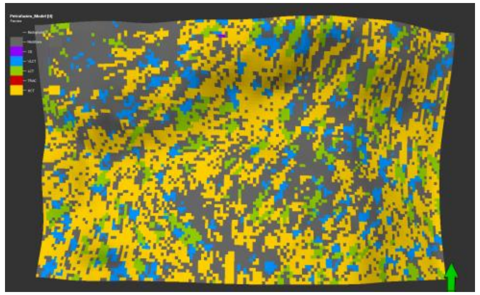
Deepwater GOM

RNR



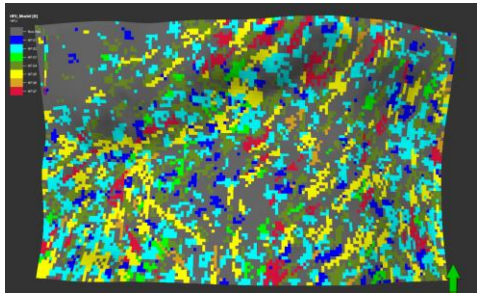
Rock Types: 2

PF



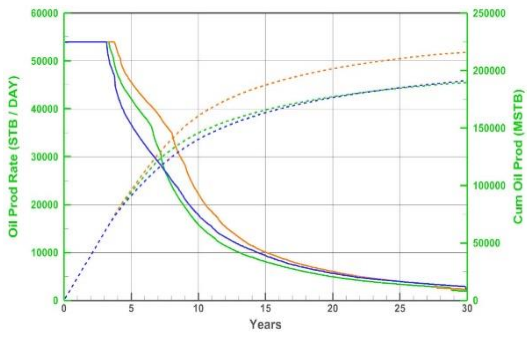
Rock Types: 4

HFU



Rock Types: 7

Simulated Profile

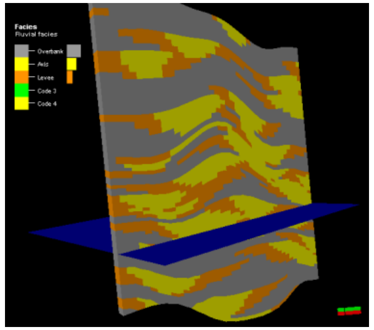


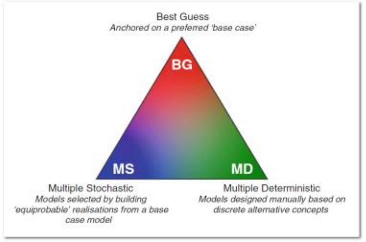
8. Quantify and model important uncertainties

- **Construct multi-deterministic models to understand the key scenarios. Use sensitivity analysis to define most impactful parameters for uncertainty modeling and then employ probabilistic methods if needed**

Reference Case

Best Technical Estimate

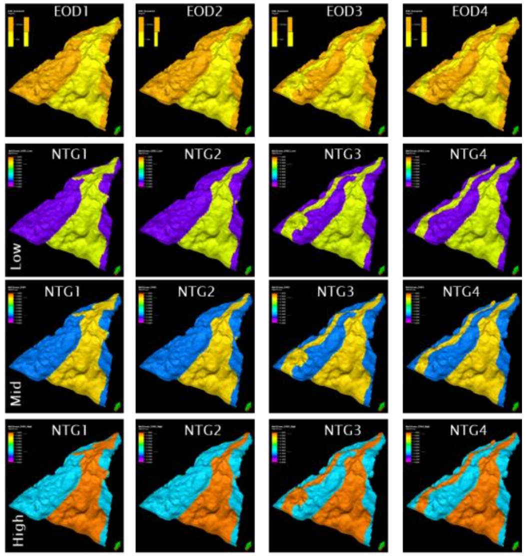




Ringrose, P. and Bentley, M. (2015)

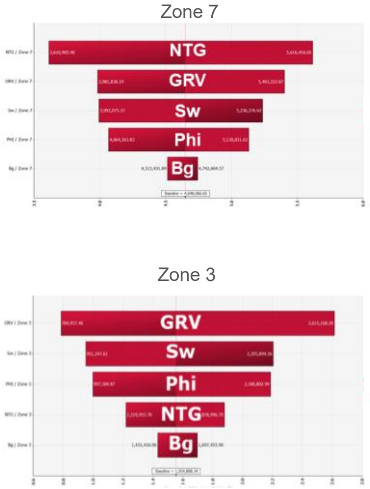
Deterministic Scenarios

Discrete Multiple Scenarios



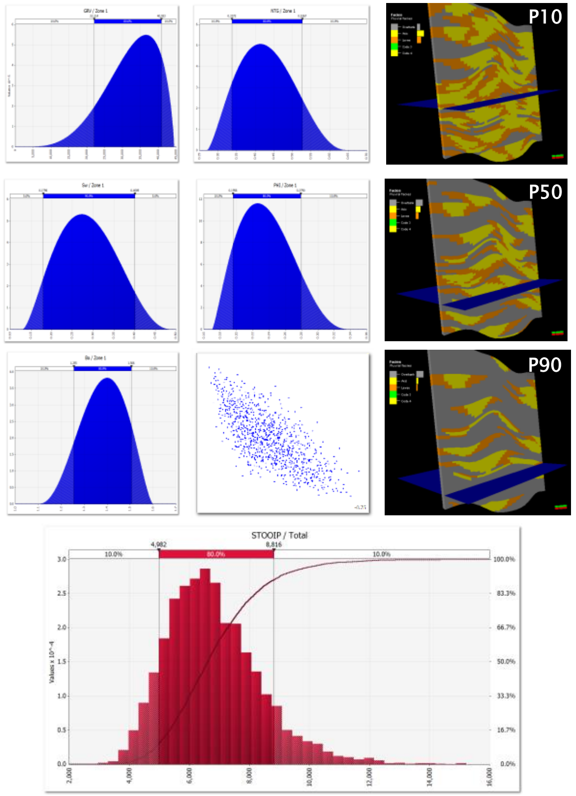
Sensitivity Analysis

Tornado Plot



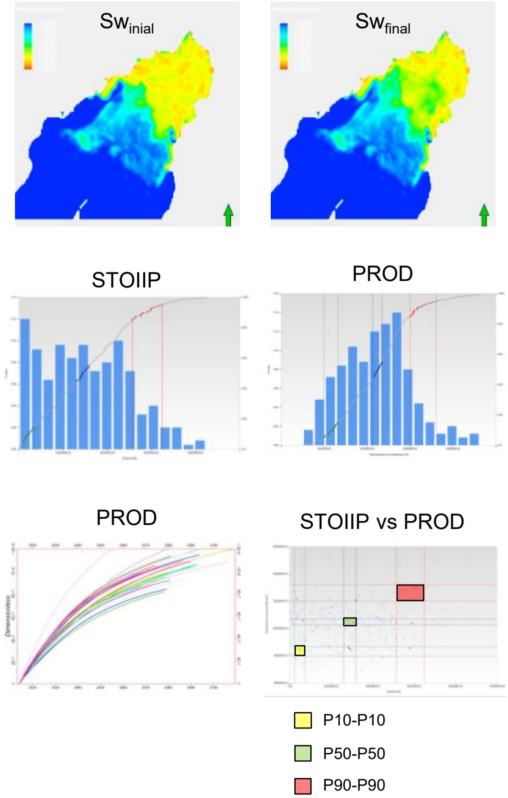
Uncertainty Modeling

Multiple Distributions with Correlations



Flow Simulation

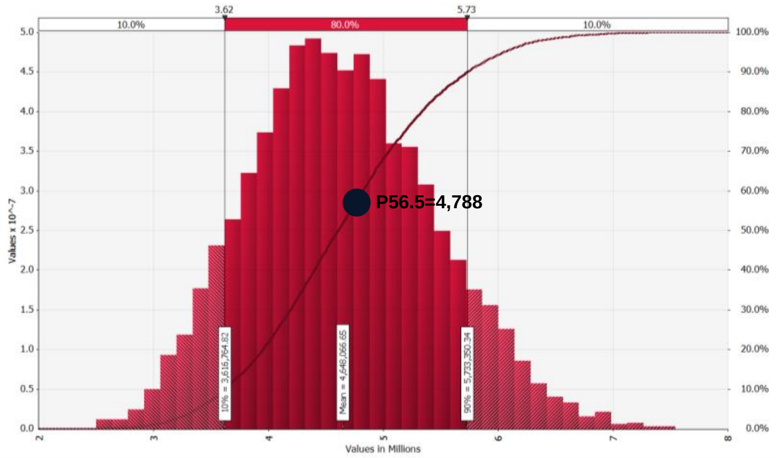
Dynamic Ranking



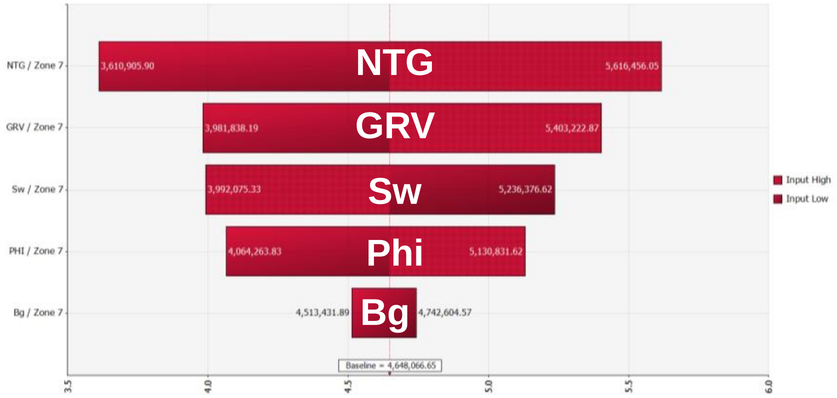
9. Focus on Commercial Impact

- Quantify the commercial value for reference case in conjunction with alternative business scenarios for downside mitigation and upside value evaluation. Investigate full range of uncertainty in decision making

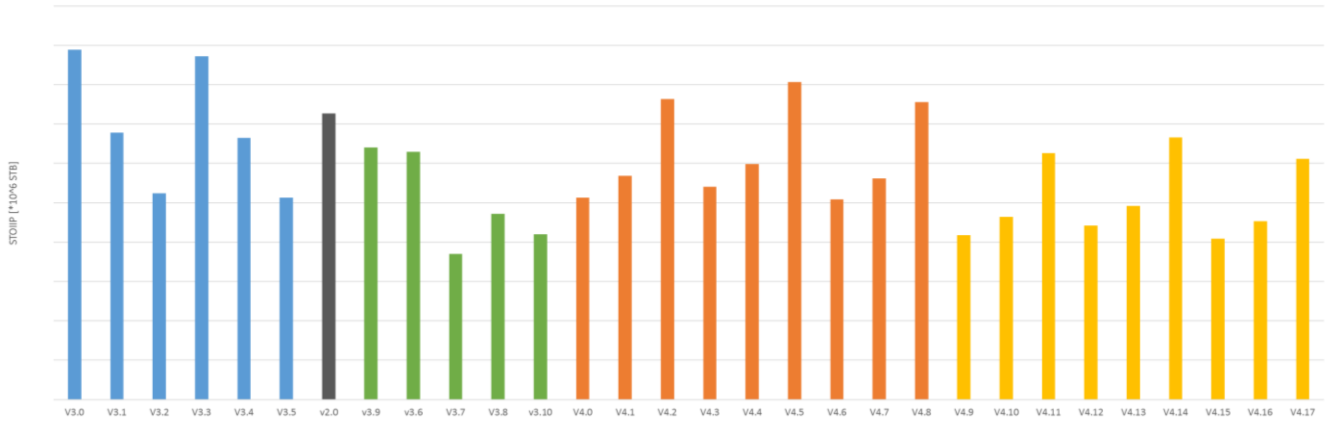
GIIP Uncertainty

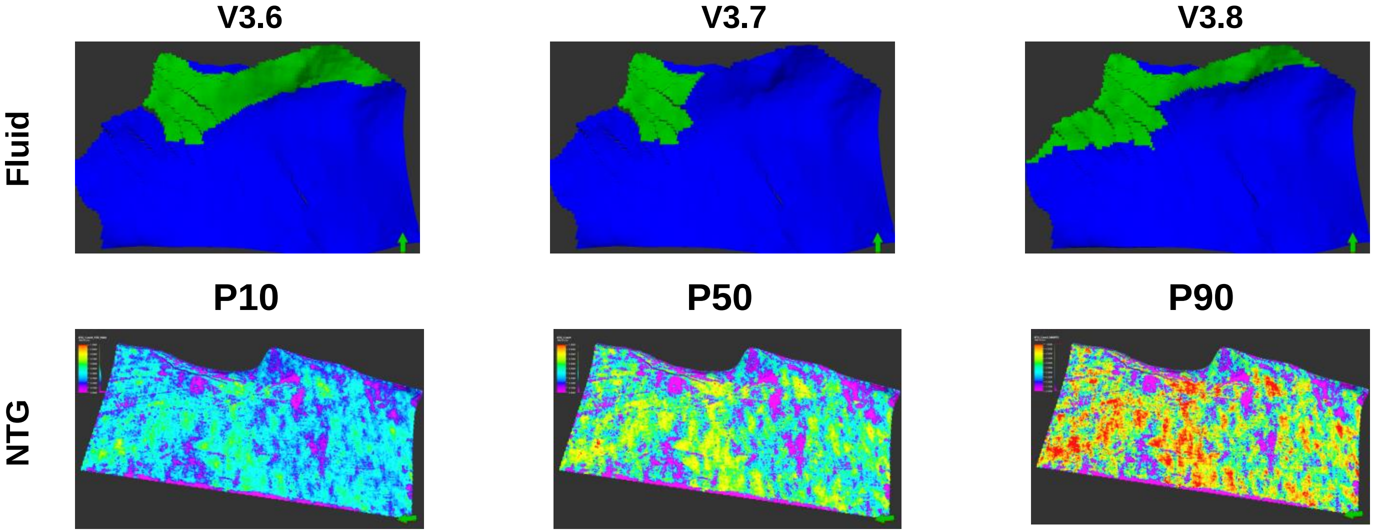


GIIP Sensitivity



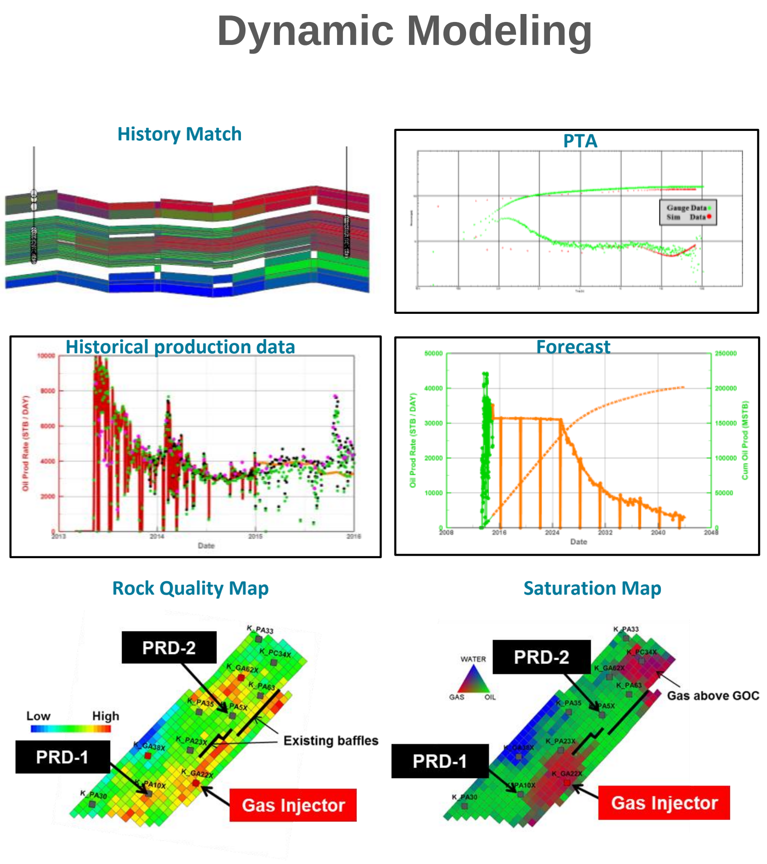
Resource Estimate

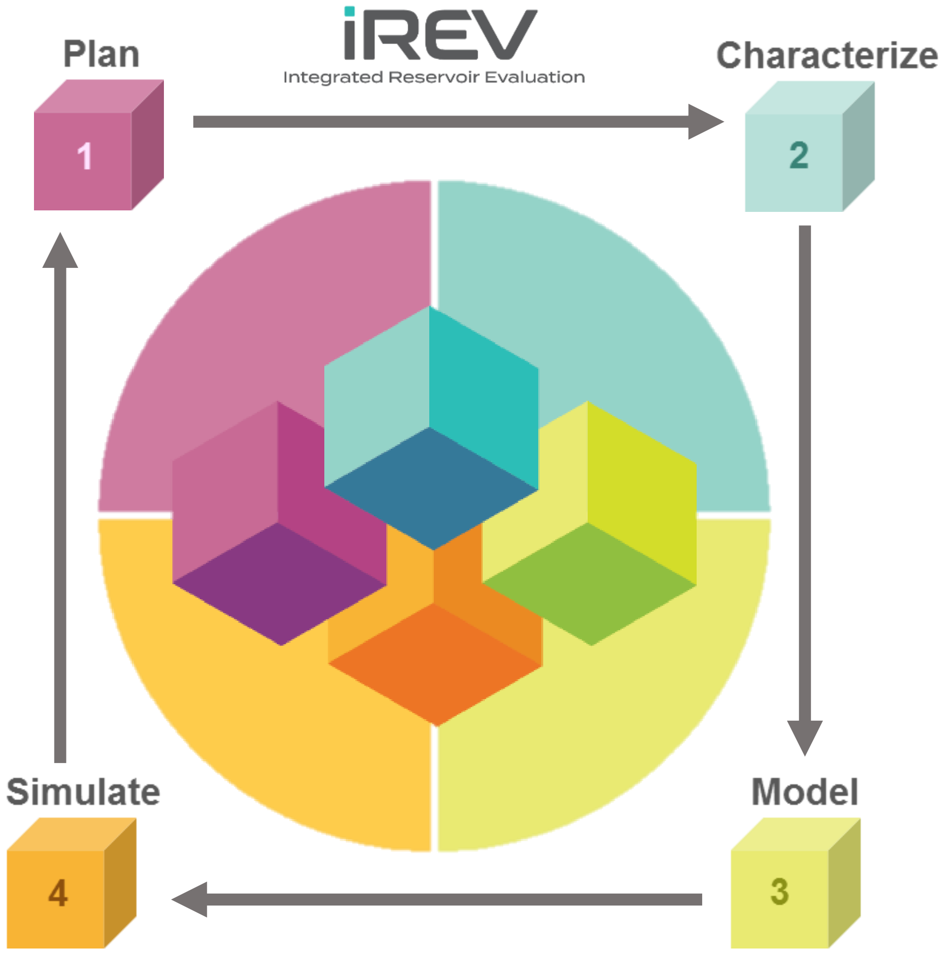


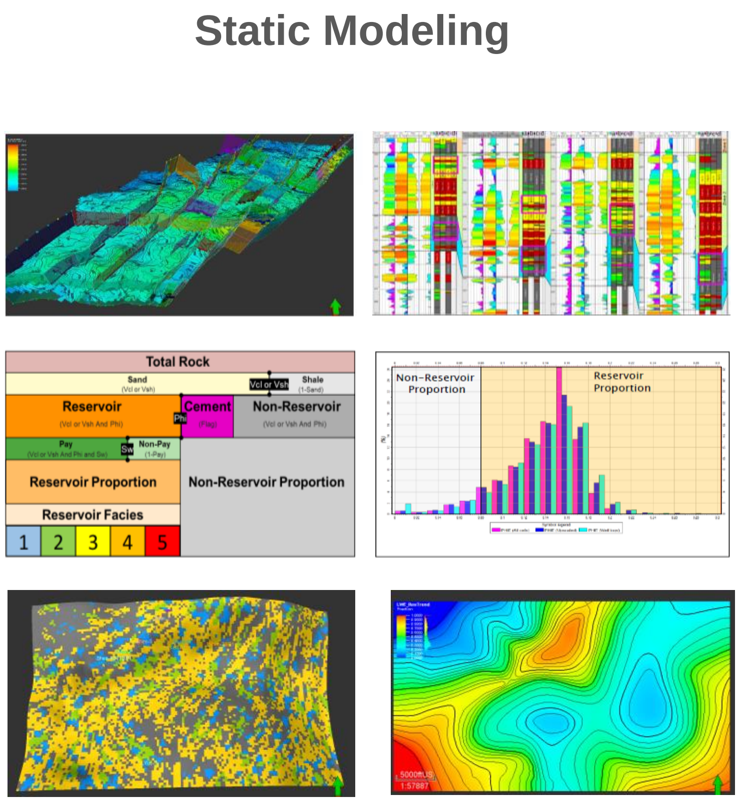


10. Incorporate Simulation Feedback

- Integrate simulation results into the static model to gain better insights into subsurface and also achieve predictive models for better forecasting







Conclusions

- Integrated Reservoir Evaluation (iREV) from characterization through modeling and simulation for the life-cycle of asset requires understanding of multi-scale reservoir elements and integration with dynamic reservoir performance
- iREV is a multi-disciplinary effort with involvement from various functions working together to develop a set of reservoir assumptions and models aligned to business needs at appropriate scale (Basin, Field, Sector, Well)
- Technical, practical and commercial variables need to be assessed prior to undertaking a reservoir evaluation study for adequate reservoir model design and timely execution
- Strategies outlined in this talk can help design objective specific (fit-for-purpose) models for business decisions
  - Define objectives, deliverables and timelines for successful planning and execution
  - Investigate scale of representation for the problem defined
  - Identify critical flow elements that control reservoir performance
  - Design a reservoir modeling process that is simple, repeatable and easily updatable
  - Represent multi-scale static and dynamic data properly at model scale
  - Honor available data and trends
  - Start simple add complexity as needed
  - Quantify and model important uncertainties
  - Focus on commercial impact
  - Incorporate simulation feedback

Acknowledgements and References

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