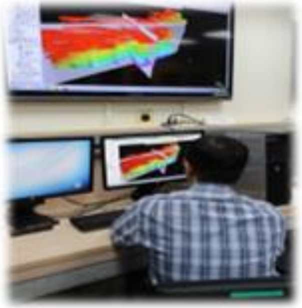


Petro-physical Characterization of Sedimentary Environments Using Collaborative New Method in Wireline logs Interpretation

Chun-Ming Chiu[1], Li-Chung Feng[1], Yun-Hao Wu[2], Andy Min Hao Wang[3], Chi-Chen Yang[1], Tim Tsung-Wen Hsiao[1]

1. Exploration & Production Business Division, CPC Corporation, Taiwan
2. Exploration & Production Research Institute, CPC Corporation, Taiwan
3. Schlumberger, Digital & Integration

Content

- Background and object
- Reservoir evaluation and Field develop plan
- Preliminary results of QI Machine Learning
- Concluding Remarks

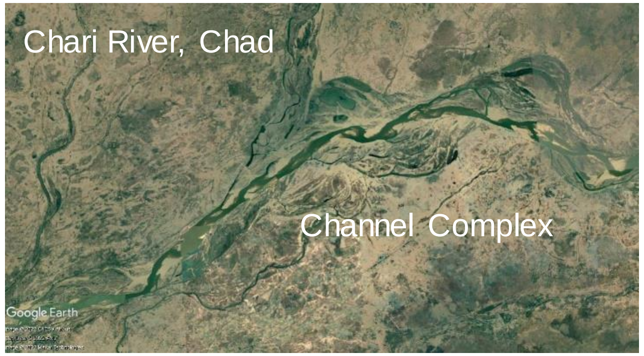
Purpose of the project

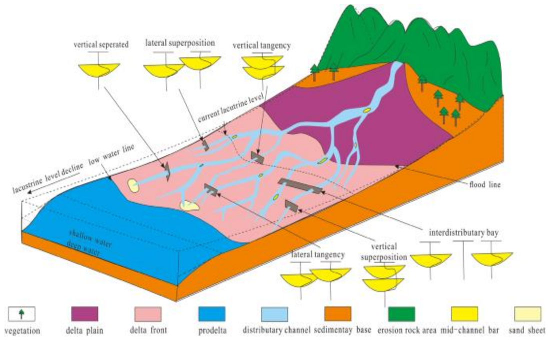
Target

- Reservoir Characterization
- Field development Plan
- Data management
- E&P collaboration

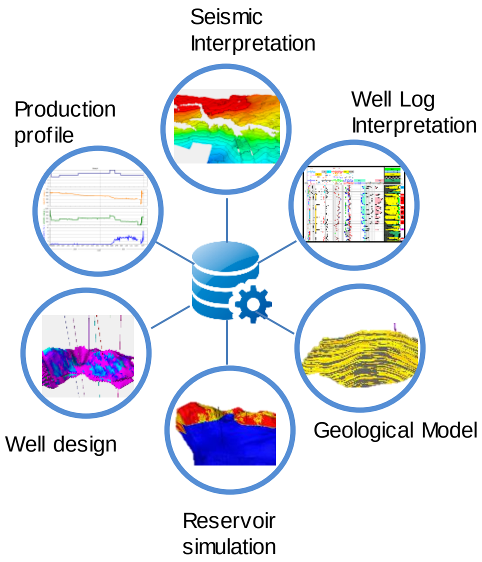
Challenges

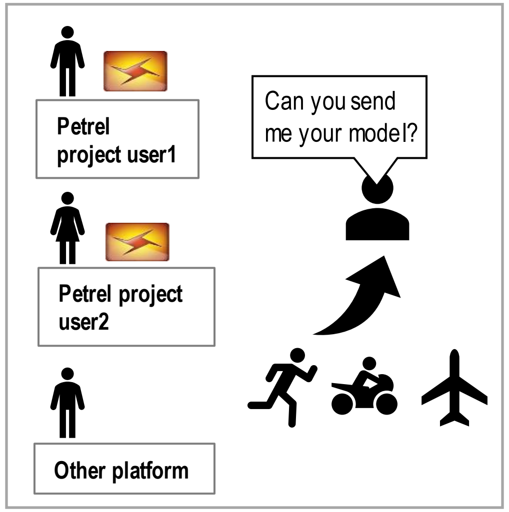
- Complex Geologic environment
- Significant vertical heterogeneity
- Data collection & QC
- Dispersed platform projects



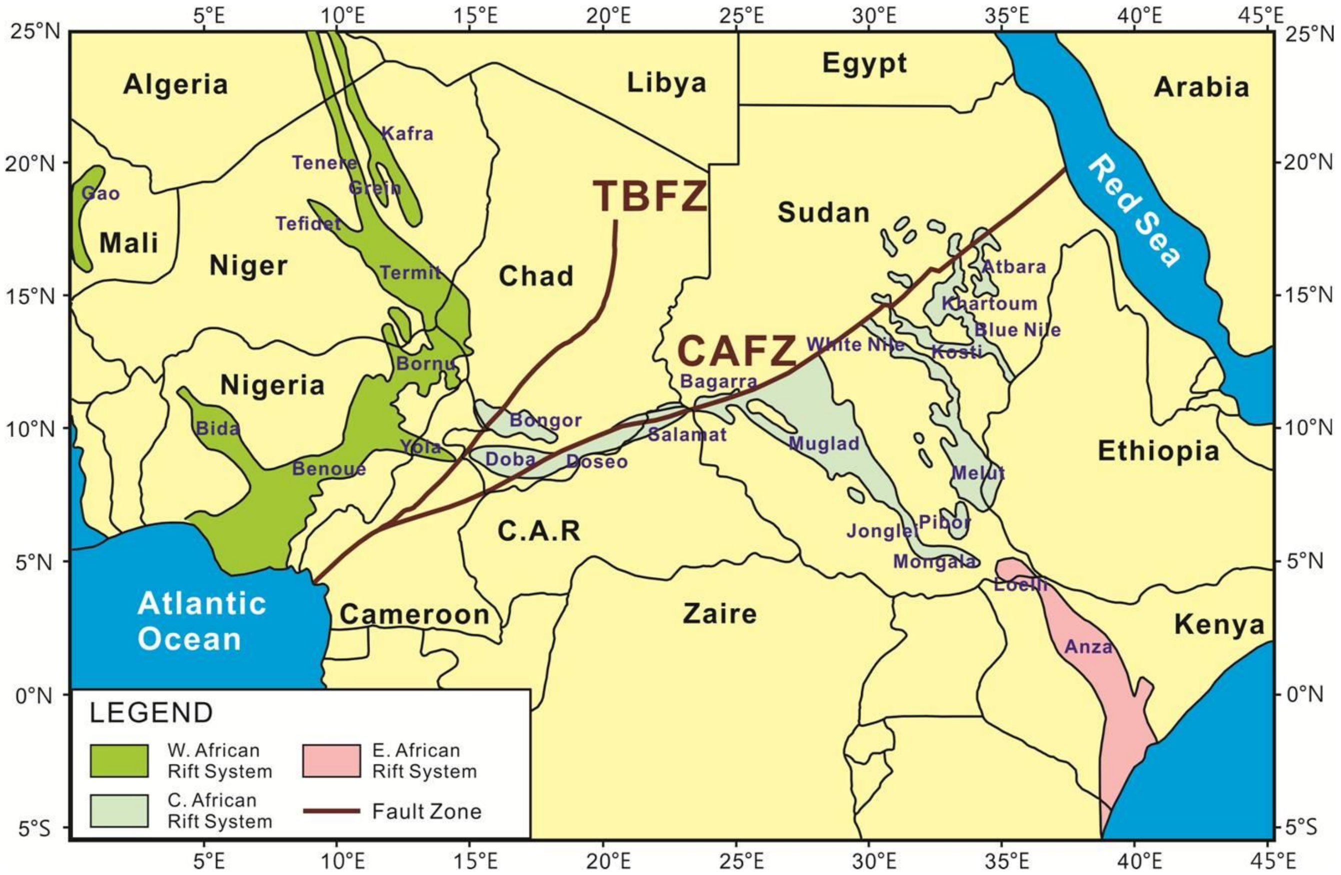


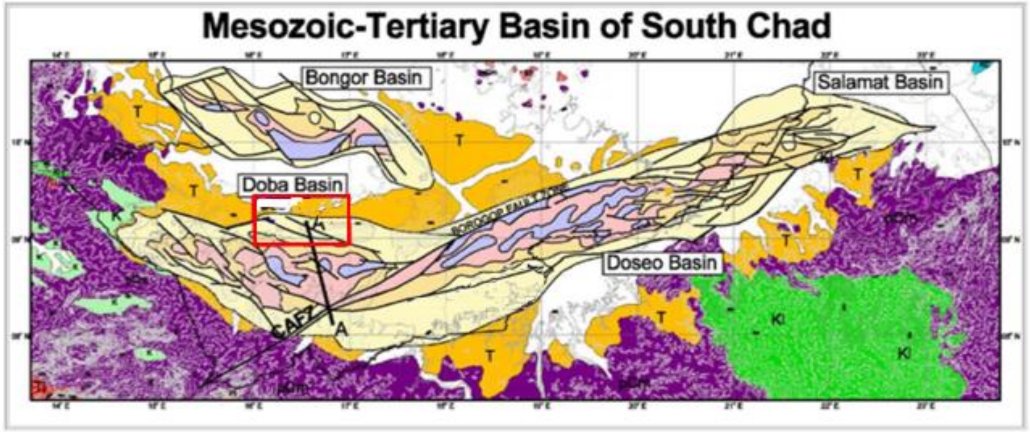
(Li et al., 2019)

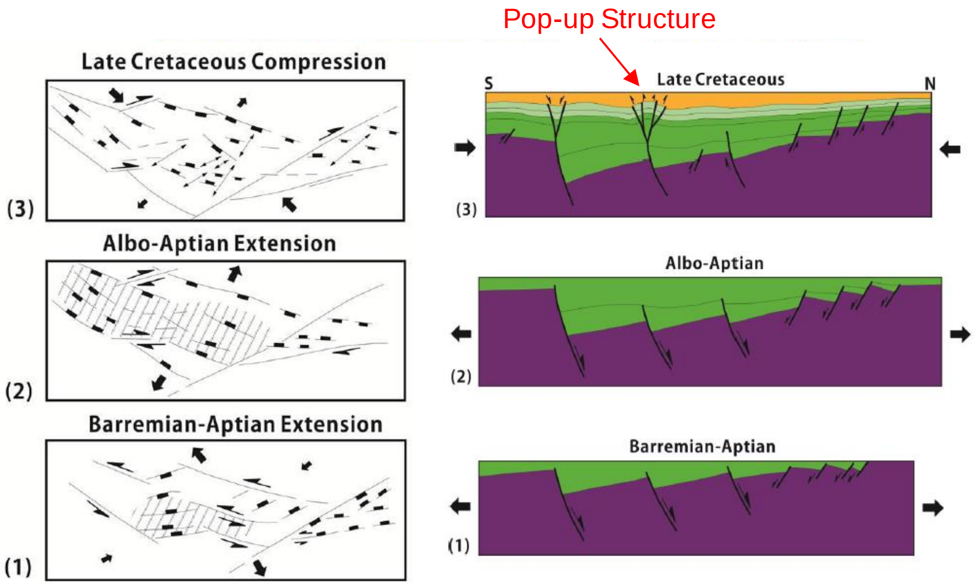




General Geology

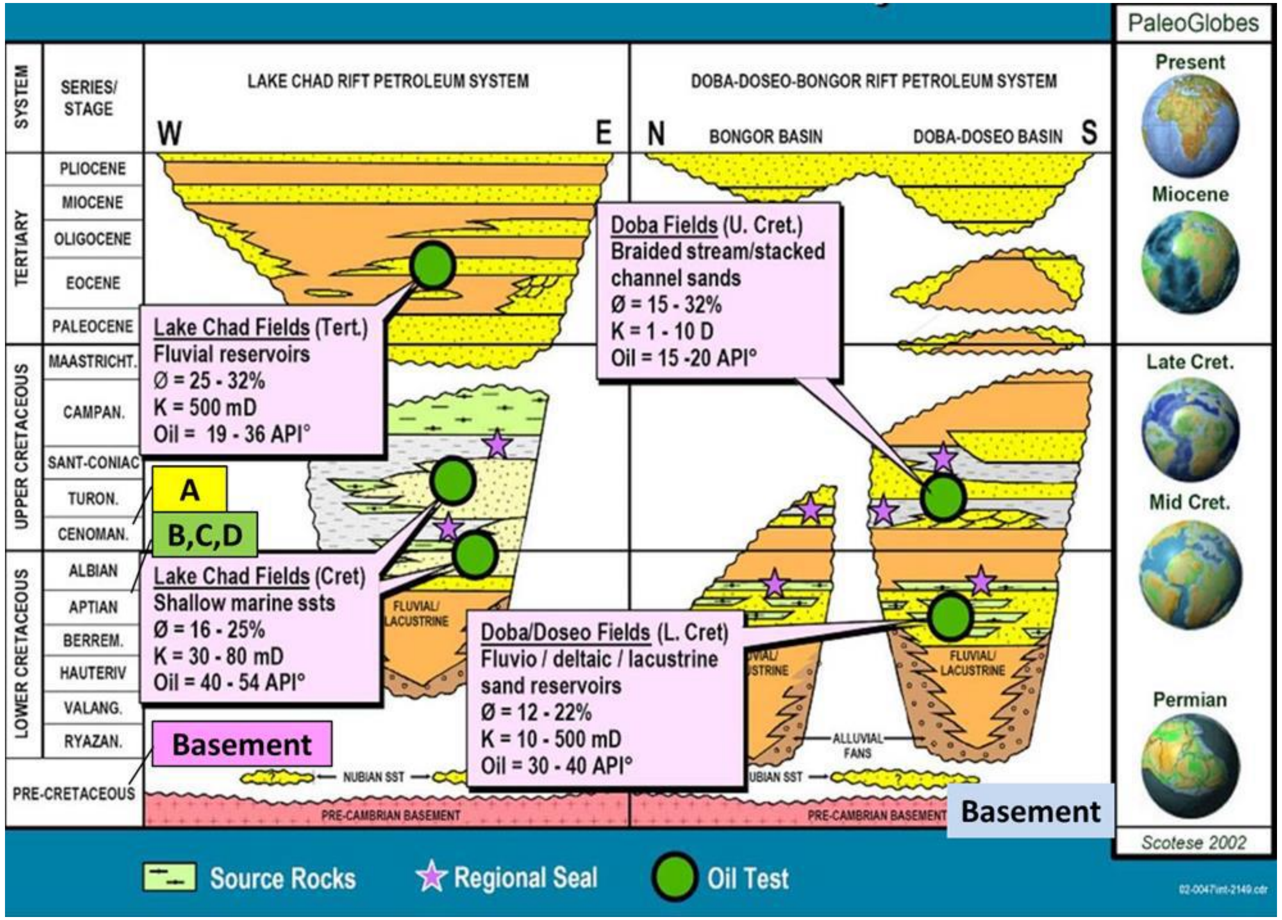




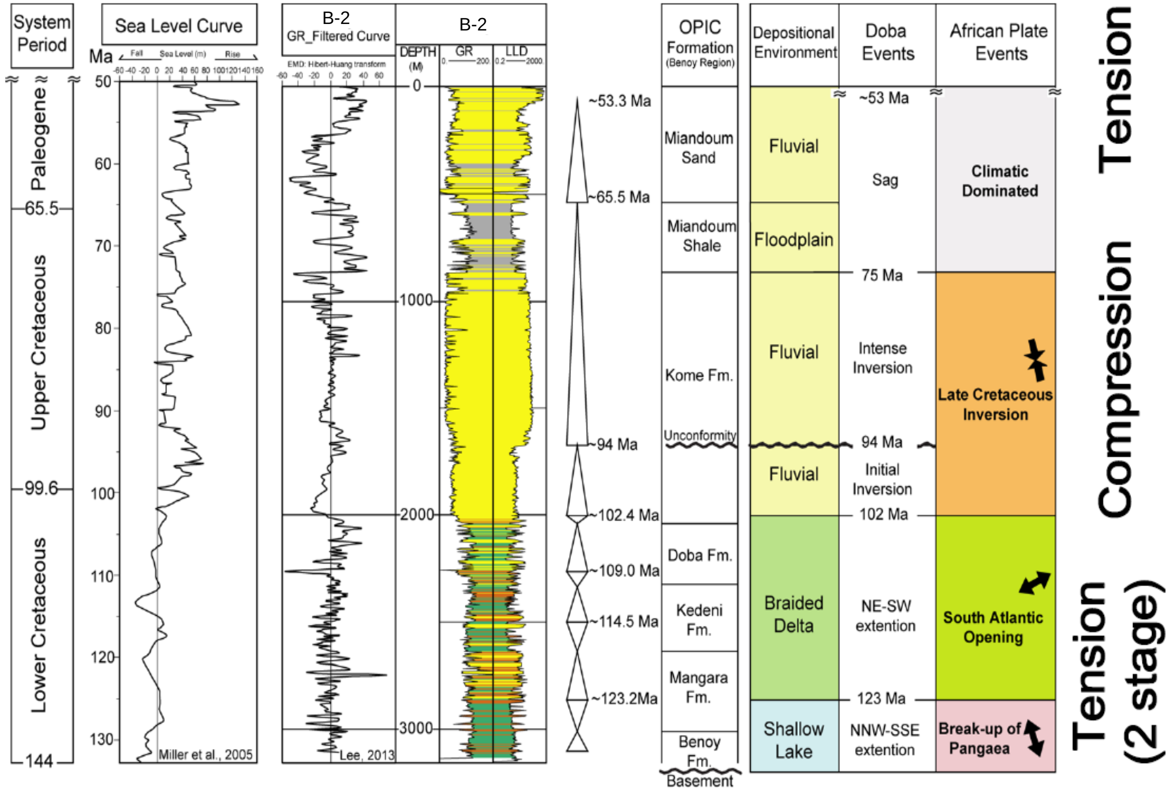


(After Genik, 1993)

General Geology

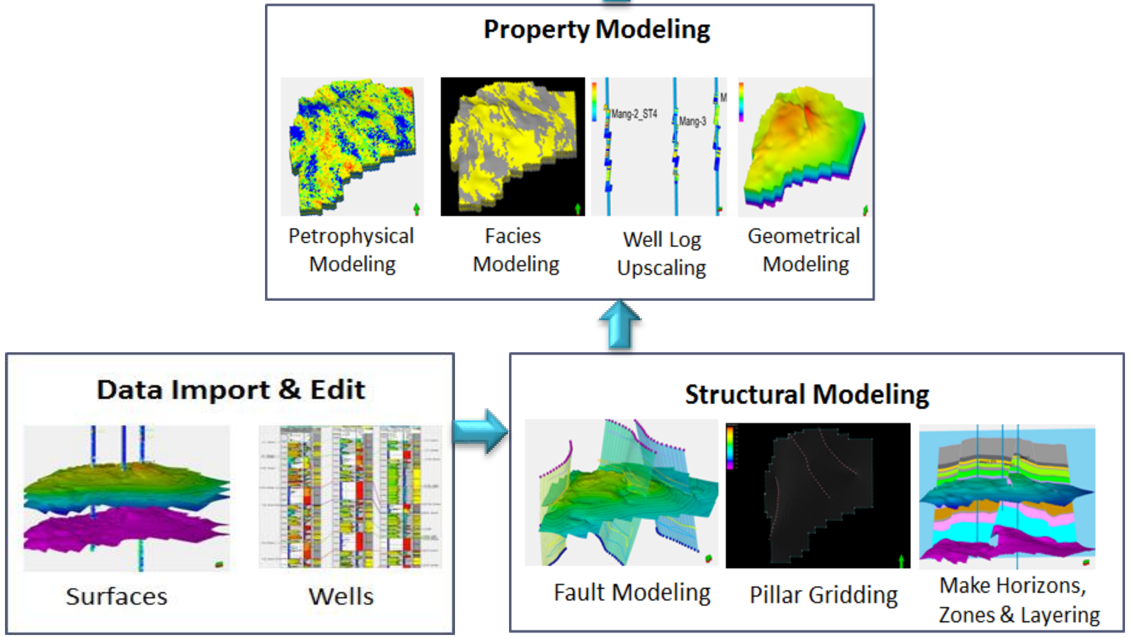


(IHS Energy Group, 2001)



Field Development Plan Optimization

Geological Model



P_{50} Simulation Model (Porosity & Facies Model)

Grid Cutoff

Permeability Modeling

OWC /PVT/ Rock & Fluid

DST Matching

Productivity / Sensitivity Analysis

Well & Pro. Design

Production Prediction

Field management!!

Opt.

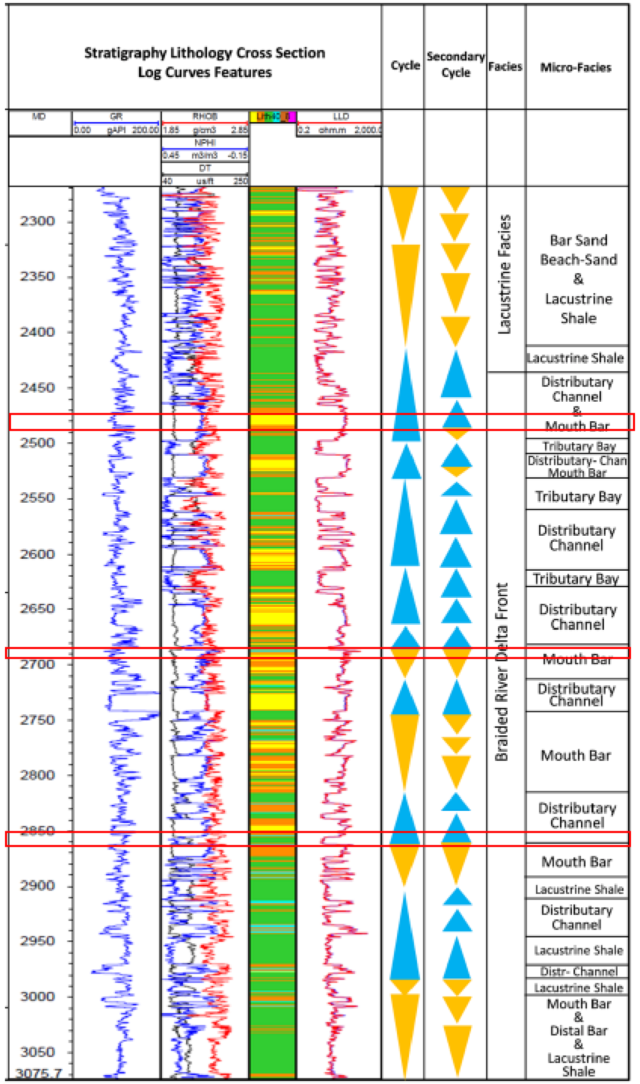
Well Plan

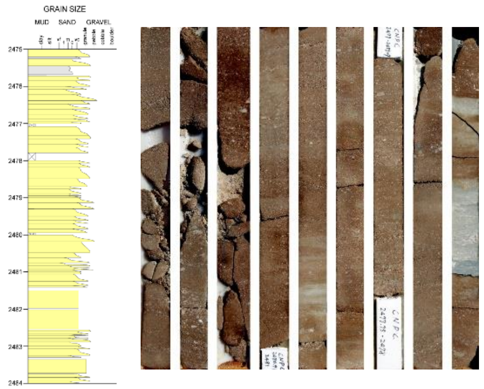
Production Profile

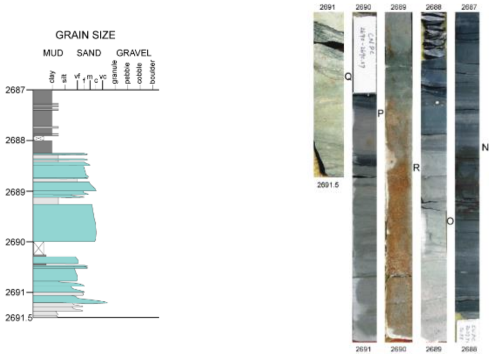
Economics analysis

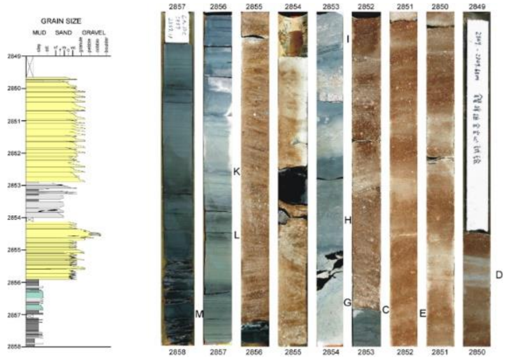
Field Development Plan

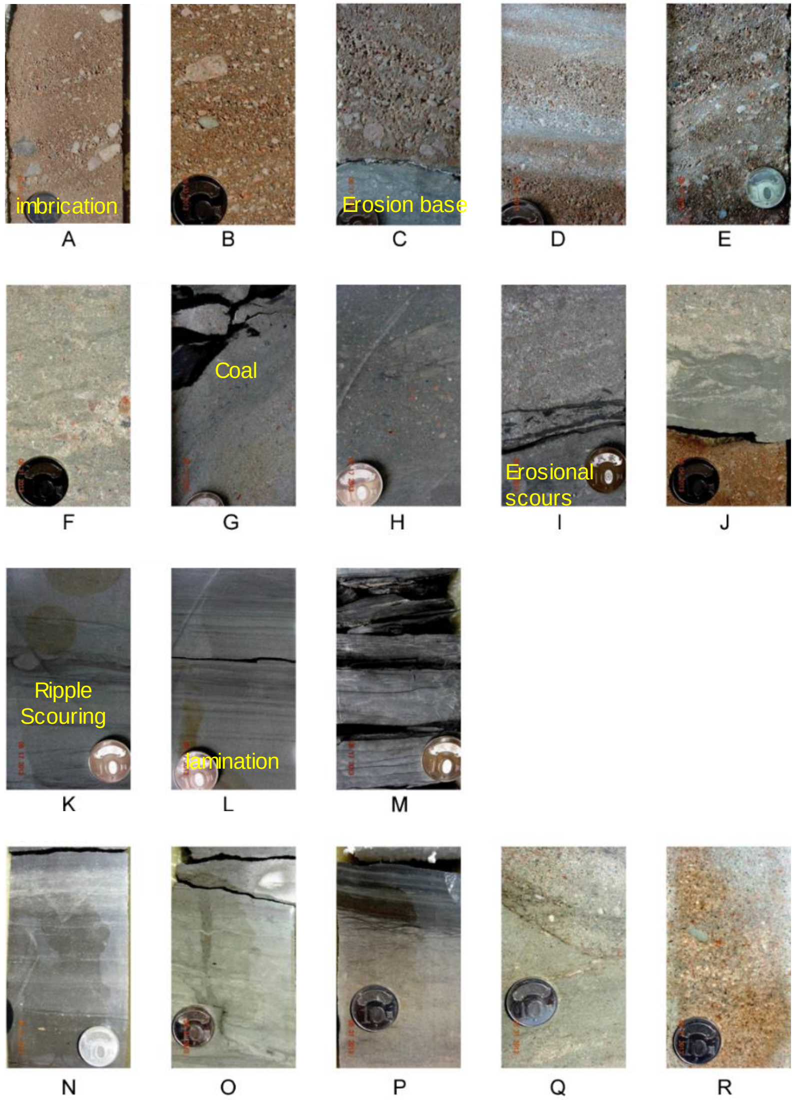
Lithology Characterization and sedimentary facies











(1) Clastic-supported coarse sand to granule

subaqueous distributary channel

(2) Matrix-supported Coarse sand to granule

Debris flow; interdistributary channel

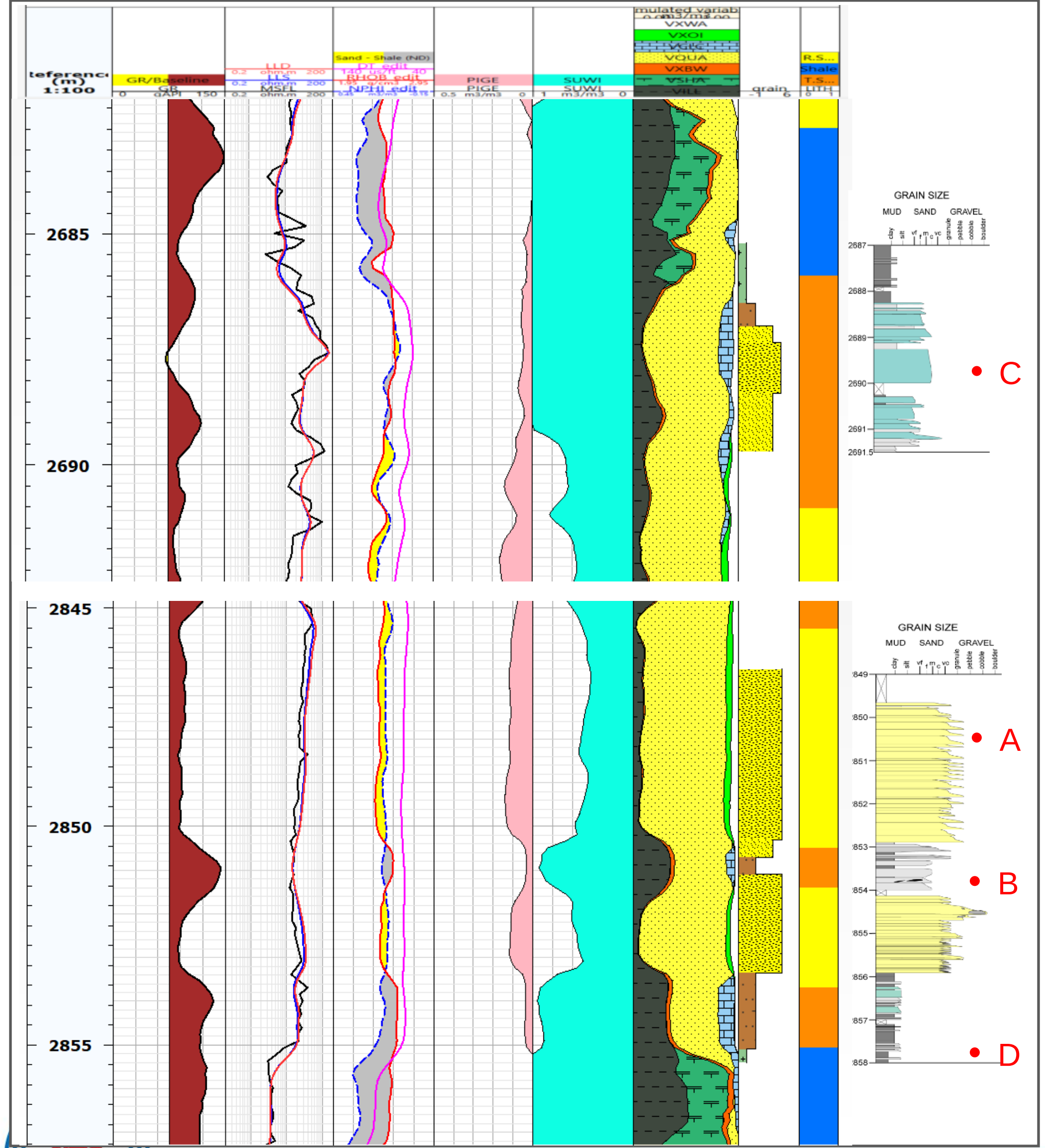
(3) Thin lamination of Ss&Sh/ Shale

Turbidity current; lacustrine

(4) Calcareous sandstone

Distal sandbar

Core-Log lithofacies integration



Reservoir Sand

Log: GR is around 90 gAPI, lower density, lower neutron, high Sonic velocity, higher resistivity; porosity>10%; shale content<40%.

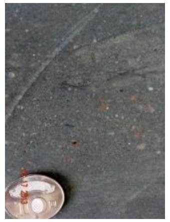
Core: Fining up medium grained, minor coarse grained, occasionally very coarse grained, moderately sorted , clear cross bedding, good porosity, heavy oil odor.

A

Tight Sand

Log: GR>100 gAPI, higher density, higher neutron, lower resistivity; porosity<10%; shale content<60%.

Core: Siltstone with very fine sand stripes in part, common argillaceous matrix, poor porosity, no shows.



B

Calcareous Sand

Log: Lower GR, high density, density>2.5, high resistivity; porosity<10%; calcite content>10%, shale content<60%.

Core: Medium grained , trace very coarse grained, sub-angular to sub-rounded, moderately sorted, trace kaolinitic cement, calcareous cement.

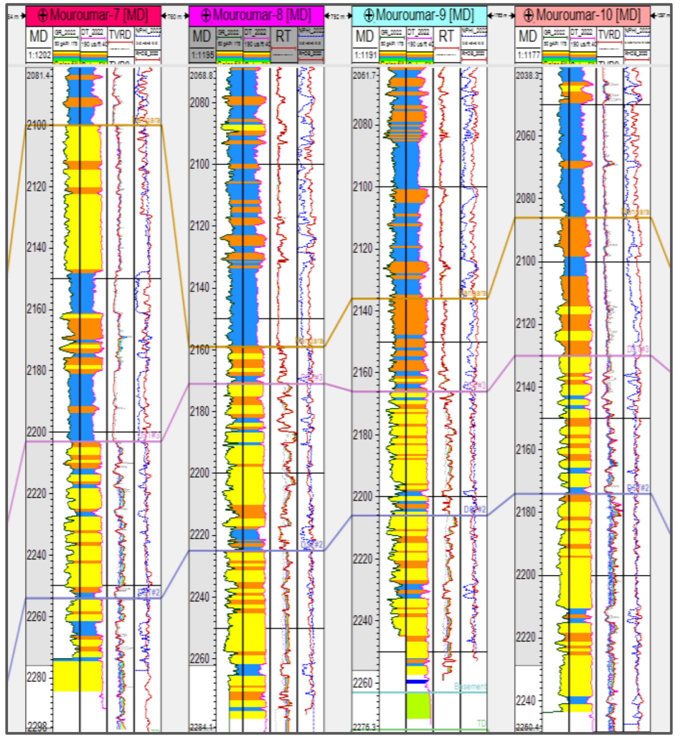
C

Shale

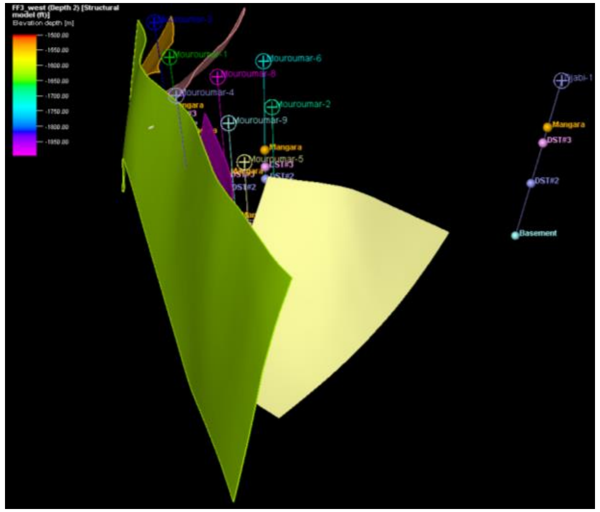
Log: Higher GR, wide neutron-density cross, low Sonic velocity, lower resistivity; shale content>60%.

D

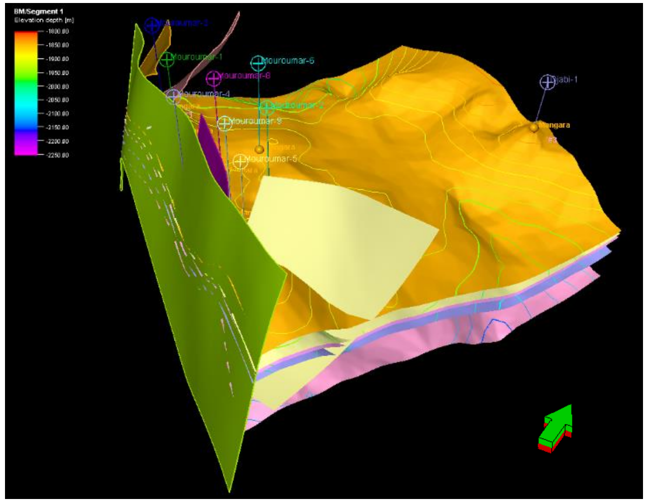
Clay Volume (Vcl)	Porosity (Φ)	Density (ρ)	Calcite Volume (Vclc)	Lith Classification
Vcl ≤ 0.4	Φ ≥ 0.1	/	/	Reservoir Sand
	Φ < 0.1	/	/	Tight Sand
0.4 < Vcl < 0.6	Φ ≥ 0.03	/	/	
	Φ < 0.03	ρ > 2.5	Vclc > 0.02	
		/	/	Shale
Vcl ≥ 0.6	/	/	/	



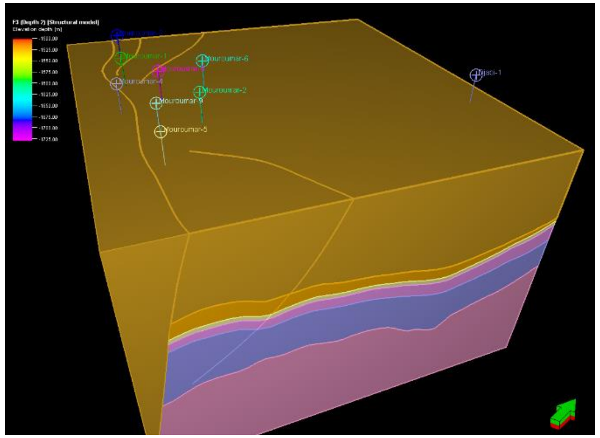
Structure Modeling



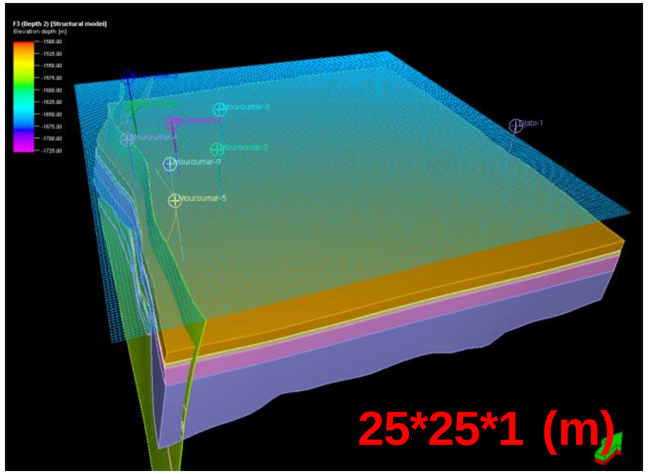
Fault Framework



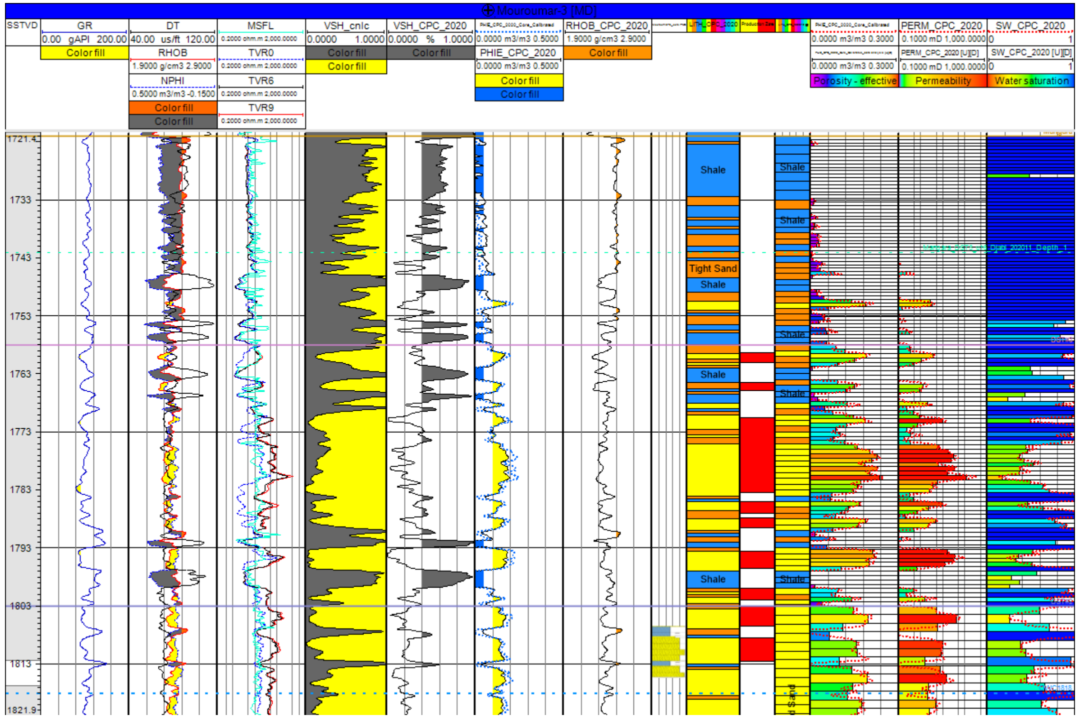
Model Construction



Model Construction

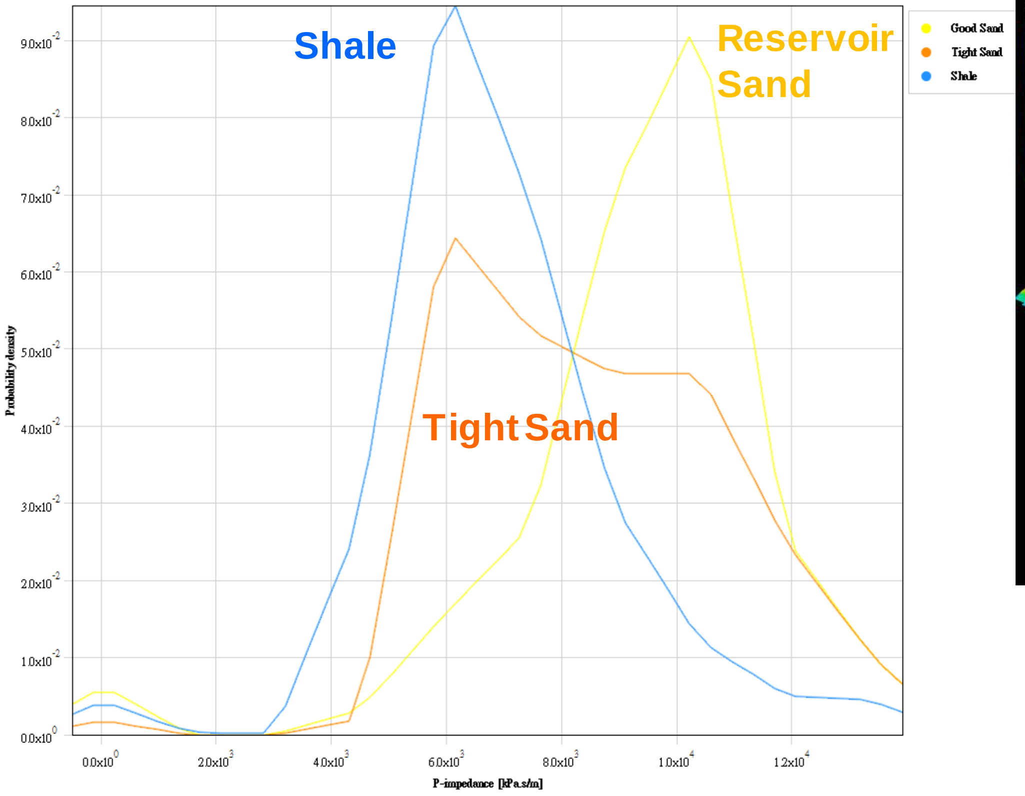


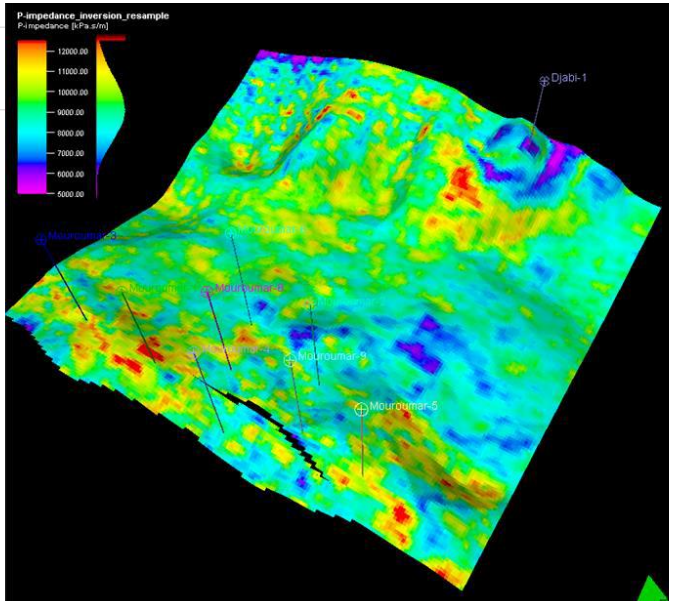
Structure gridding

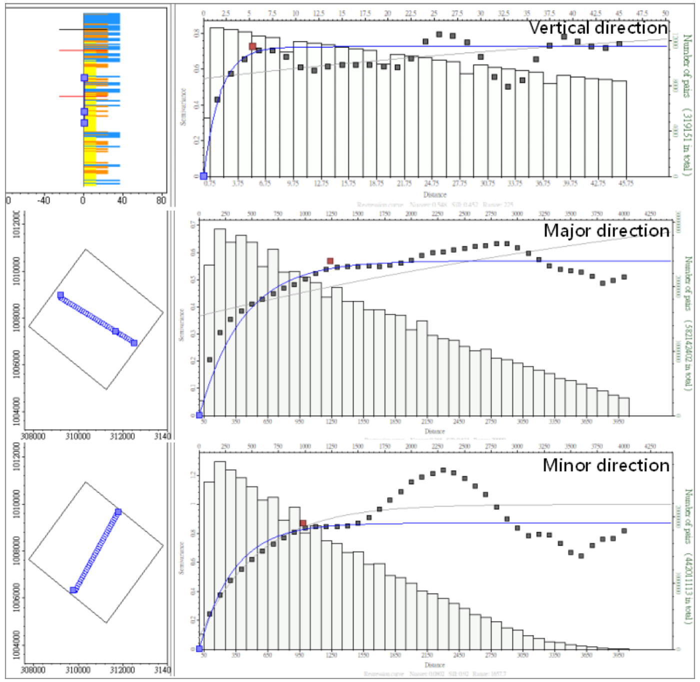


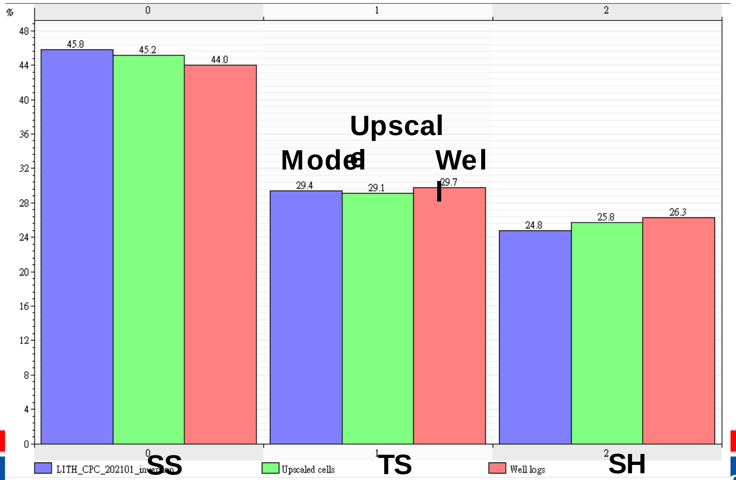
Well data upscaling

Property Modeling

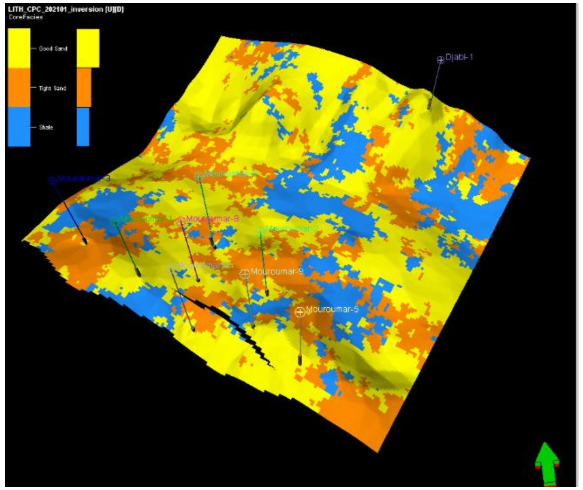




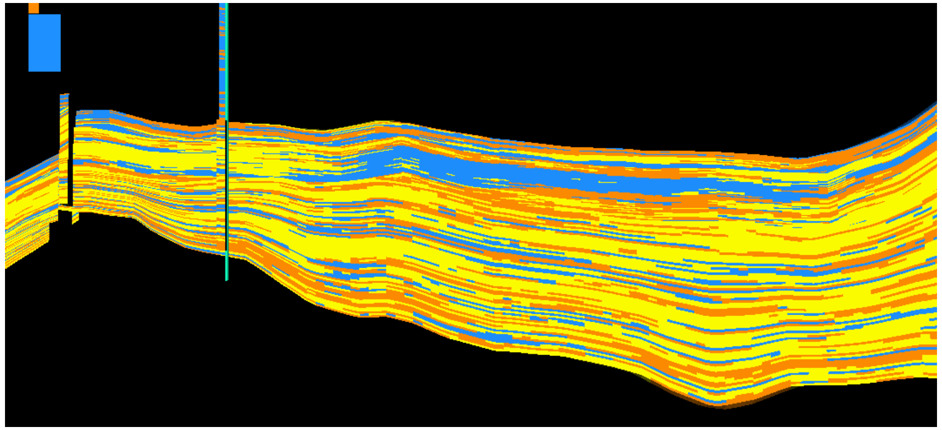


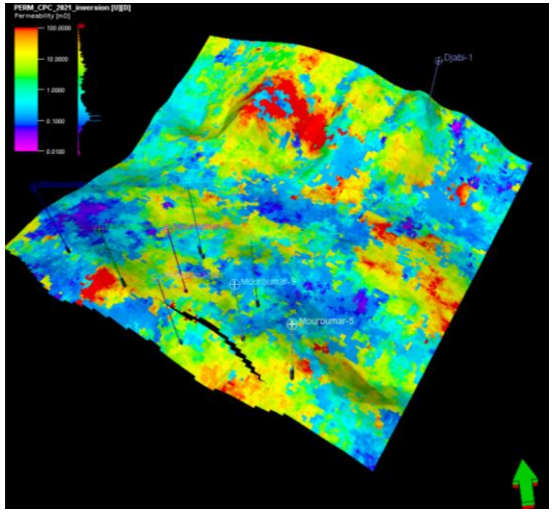


Property Modeling

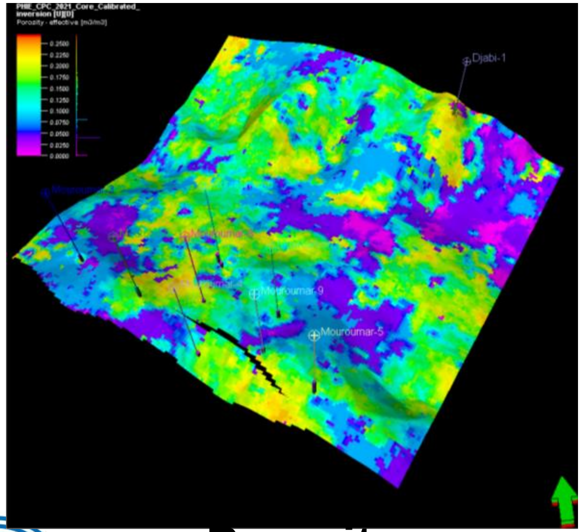


Lithology

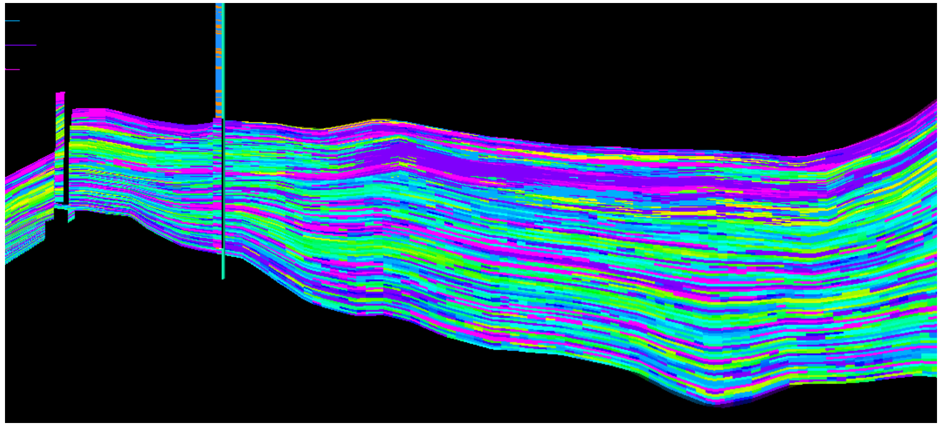


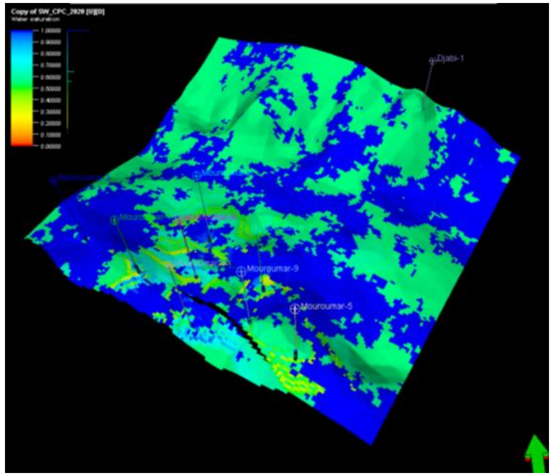


Permeability



Porosity



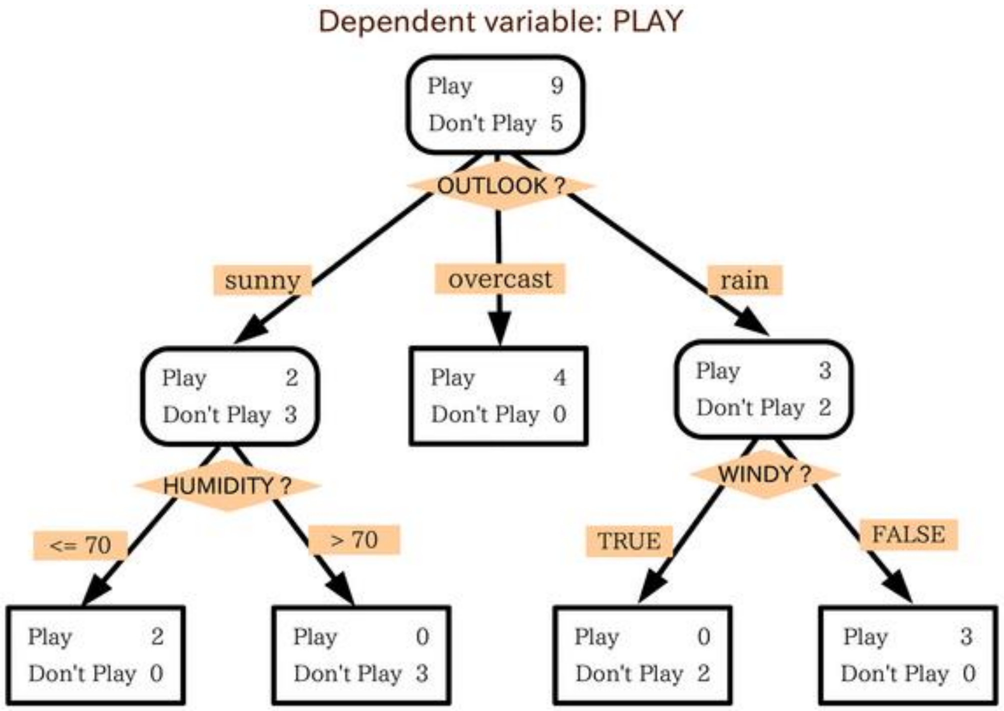


Water Saturation

Decision Tree

- Machine Learning Module in Petrel

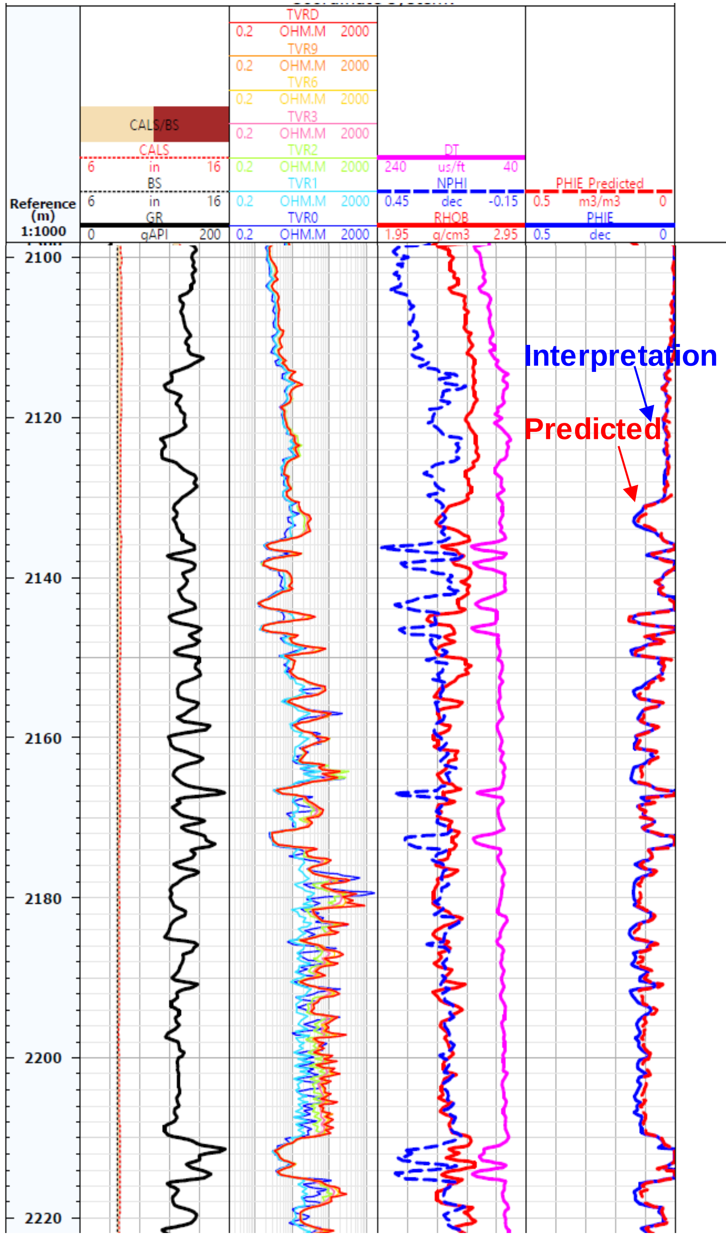
- Case Study
  - Porosity curve prediction
  - Shear wave curve prediction
  - porosity cube prediction



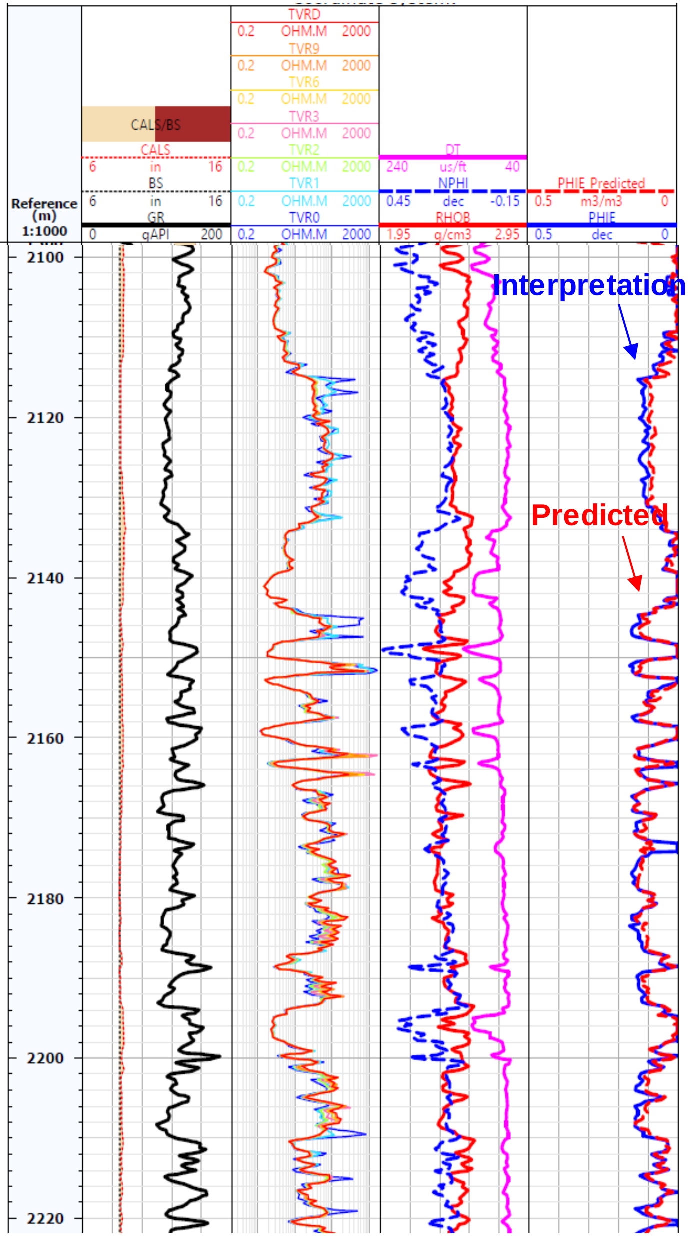
Porosity Log prediction

- Conventional logging curves of 8 wells are used for training
  - Gamma Ray (GR), Deep Resistivity (RT), Medium Resistivity (RLA3), Invaded Formation Resistivity (RXOZ), Density (RHOZ), Neutron (TNPH), Sonic (DT), photoelectric effect (PEFZ)
- Target: Effective Porosity (PHIE)
- Results curves are mostly consistent with manual interpretation

Well M-10

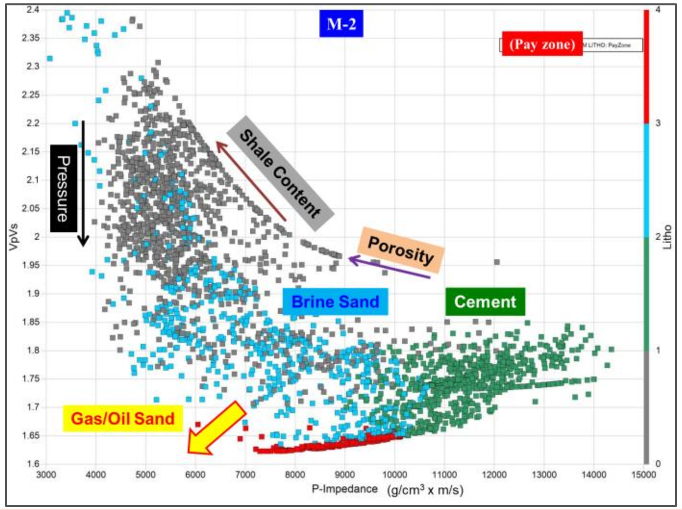


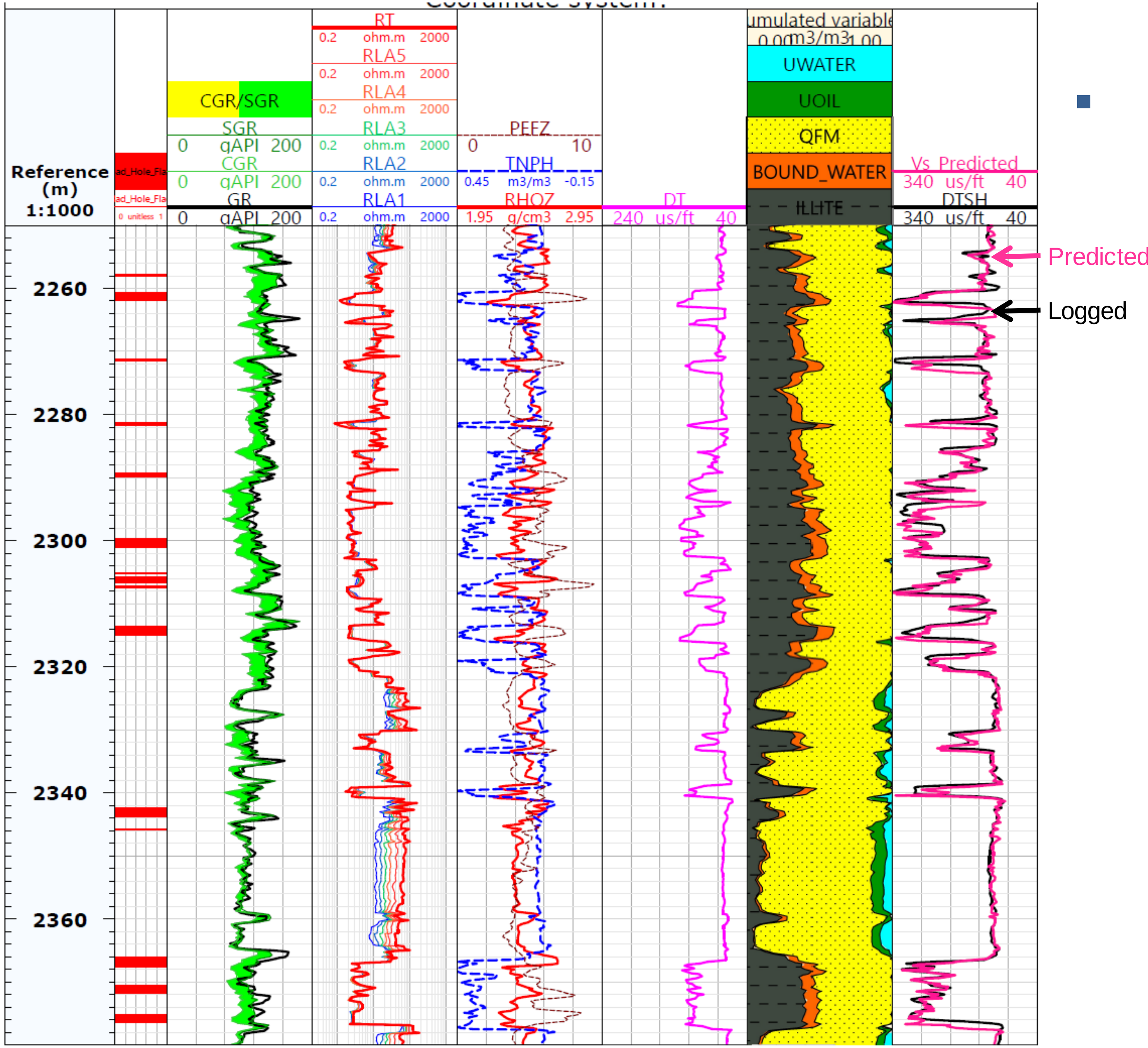
Well M-12



Shear wave prediction

- Conventional logging curves are used for training
  - Gamma Ray (GR), Deep Resistivity (RT), Density (RHOZ), Neutron (TNPH), Sonic (DT)
- Target: Shear Slowness (DTSH)
- The predicted curve matches well with actual logged curve.
- discrimination of reservoir fluid





Porosity Cube prediction

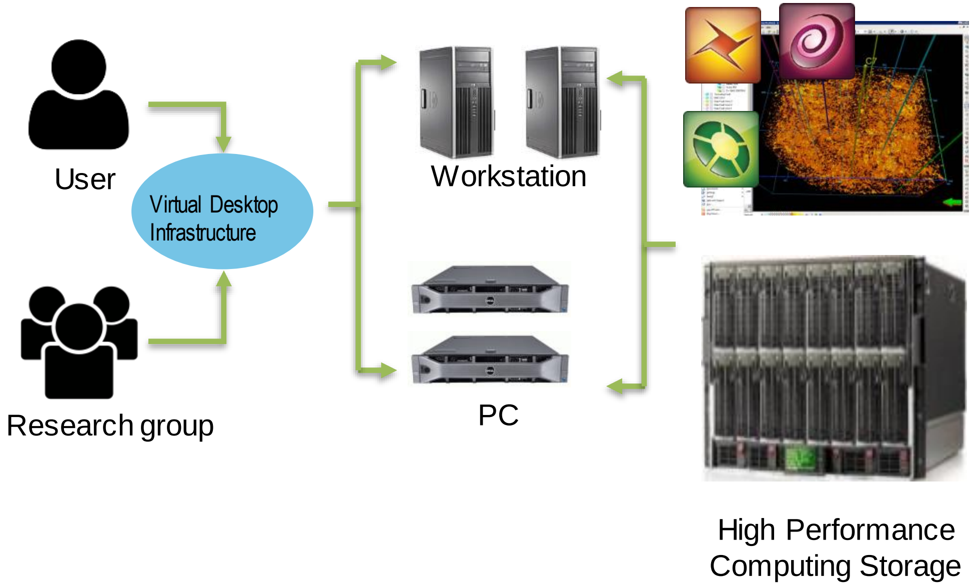
- <u>Training model :</u>

- <u>Prediction:</u>
- Input: P-impedance, Density and Vp/Vs cube.
- Output: Porosity Cube
- <u>Result</u>
  - Match well with actual logging curve

Data integration & collaboration

Challenges:

- Data storage in PC or external disk
- Time-consuming for data searching, preparation and transfer.
- Human errors in data import (CRS, datum, units)
- Duplicated Data
- Research result display (color bar, template, well-section, workflow)



Workflow

- Data index, search, access
- Data share, collaboration
- Data filtering and management
- Resource evaluation workflow, reservoir simulation workflow
- Play Chance Mapping

Background

Sedimentary Facies; well correlation

Seismic Interpretation; seismic well tie; Attribute analysis

Velocity Model; Structural geological models

Face model; Property models

Volume calculation; Reports & Graphs

geological models: Property models, fault analysis, water drive, water drive parameters, grid

Fluid Properties, fluid model, initial conditions

Rock physic functions, relative permeability, capillary pressure

Well head; Well path; Completion design; observed data, VFP

Development strategy & simulation, History matching, Uncertainty and Optimiaztion

Concluding Remark

- The sedimentary facies and reservoir characterization was analyzed by core-Log lithofacies integrating.
- The resource evaluation and field development plan were completed based on the geological model from deterministic inversion.
- Case study of QL Machine Learning suggested the predicted porosity and shear wave match well with manual interpretation and actual log data, respectively.
- The Petrel E&P platform and Studio improved efficiency in data management and collaboration among researchers.

Thank you for listening