Integration of Geology and Geophysical Data in Reservoir Characterisation - A Case Study of the K Field*

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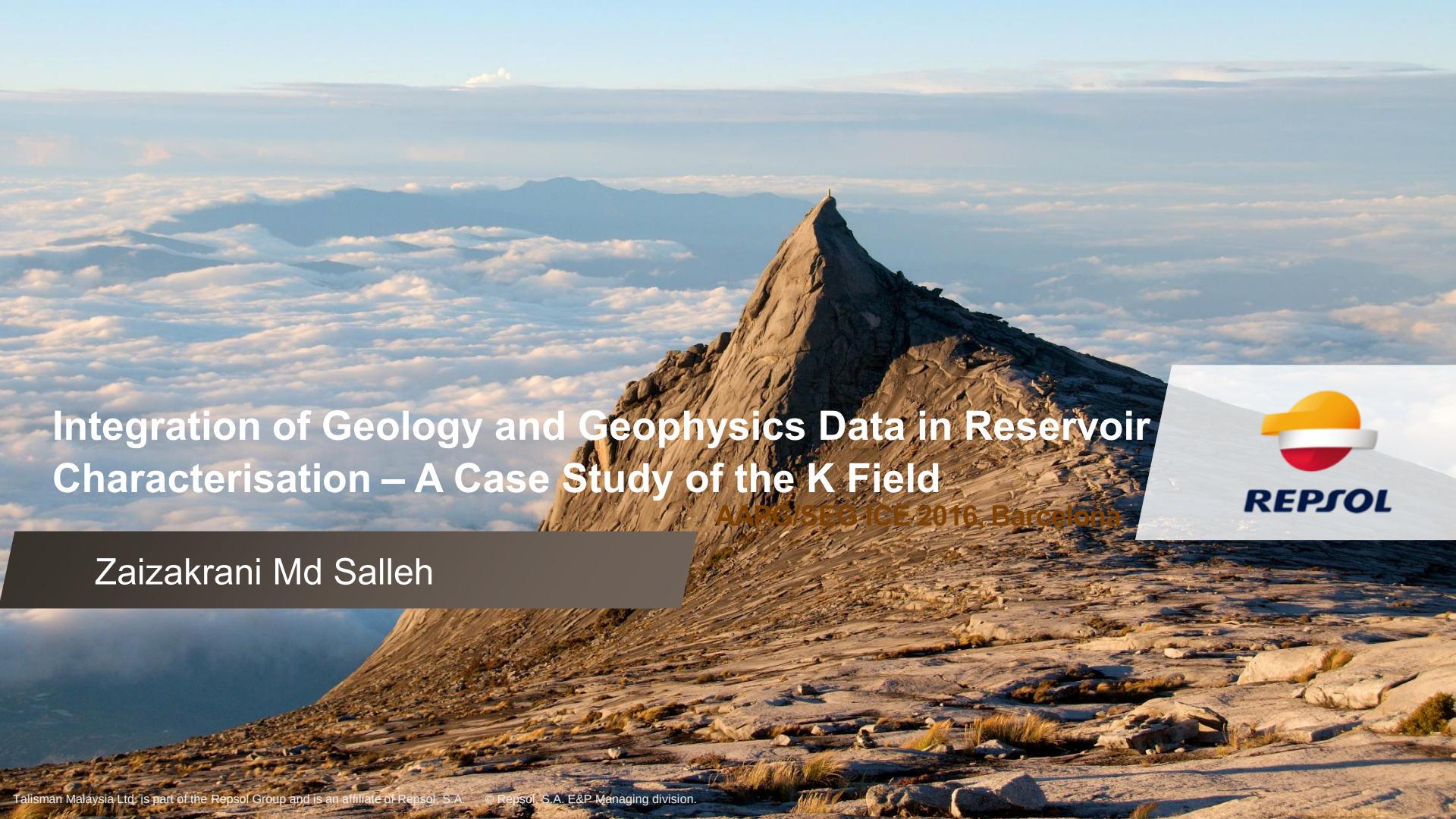
Abstract

The K field, located offshore Sabah on the island of Borneo, was discovered in 1989. The main accumulation is dip-closed against a major SW-NE trending growth fault where some forty sand units formed the major part of the hydrocarbon accumulation. The reservoir consists of stacked marine shoreface sandstones of Miocene age and hydrocarbon occurs as oil and associated gas caps. To date, more than 40 development wells have been drilled since 1995. Talisman Malaysia Limited (TML) took over the operatorship of this matured oil field from the previous operator in 2012 and undertook a comprehensive review of all the sub-surface opportunities with a view of preparing a full redevelopment workscope of the field. An integrated geology and geophysics subsurface review was conducted to generate a full field 3D static model mainly to provide input for dynamic reservoir simulation and history matching. This paper describes the G&G integration process and examples of utilization of seismic input into the 3D static modeling process. One of the target reservoirs, X1, has a net sand thickness less than 60 ft, below tuning thickness. A broadband re-processing sequence was engaged and a high-resolution stochastic inversion was carried out on the re-processed data to map this reservoir. The resultant P-impedance and S-Impedance cubes were used to generate lithofacies probability cubes through a classification technique in the Vp/Vs-P impedance domain. In order to establish a relationship between seismic attributes and reservoir properties, cross-plots of seismic amplitude and P-impedance against reservoir properties such as volume of shale, net sand thickness, water saturation and porosity were performed from the target reservoir unit. Based on the cross-plots, stronger seismic amplitudes and lower AI generally represent better reservoir quality. The sand probability distribution map of the target reservoir shows better developed reservoir towards the northern region. This trend has been used as a soft constraint to guide the reservoir modelling process away from the wells. The P impedance

distribution map also highlights the lower impedance in the northern region, which could be attributed to the reservoir depletion. The MDT pressure data collected from the recent drilling campaign indicates less pressure depletion in the northern region than the southern region of the field. An infill well has been planned to drain the oil in the northern region based on this study.



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AAPG/SEG ICE 2016, Barcelona

Zaizakrani Md Salleh

K Field Overview

Geological Background

Geophysical Study

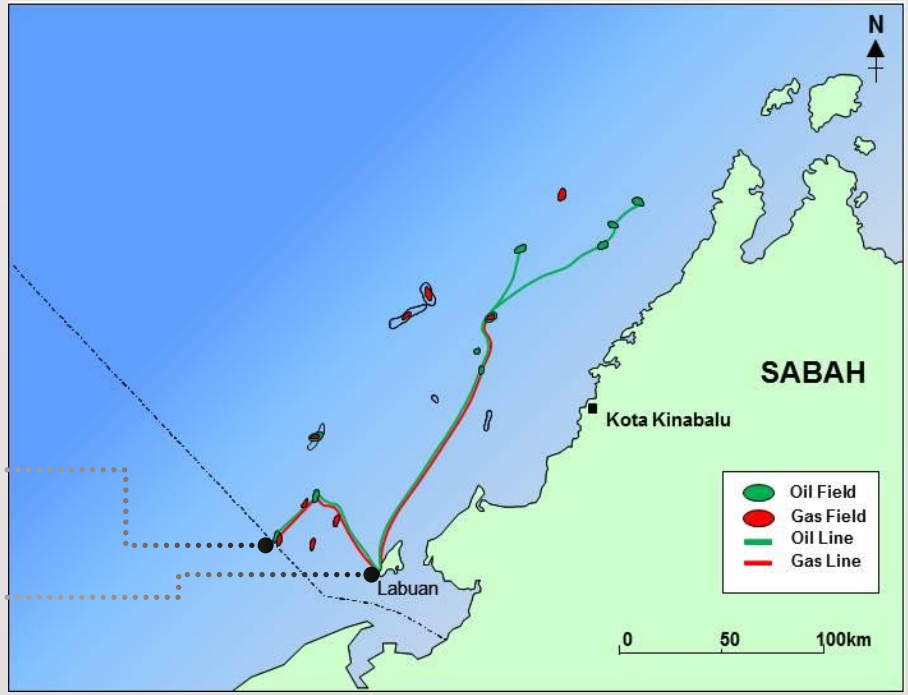
3D Static Modelling

Case Study – X1 Reservoir

Summary

Field Overview

Location Map



Case Study Field

Labuan Island

Block Details

- **K Field:**
  - Commencement: Dec 2012
  - Operator: Talisman Malaysia Limited
  - Partner: PETRONAS Carigali
  - 20 years License
- **Location**
  - 54 km offshore Labuan
  - Water Depth: 56 m
- **Field Discovery:** 1989
- **> 40 Development Wells**

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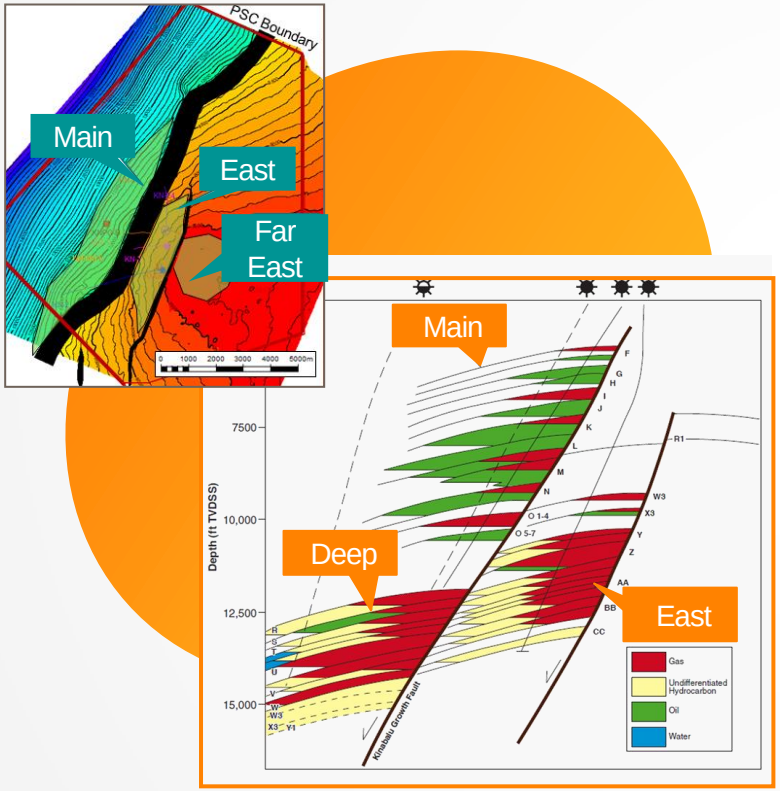
Geological Setting



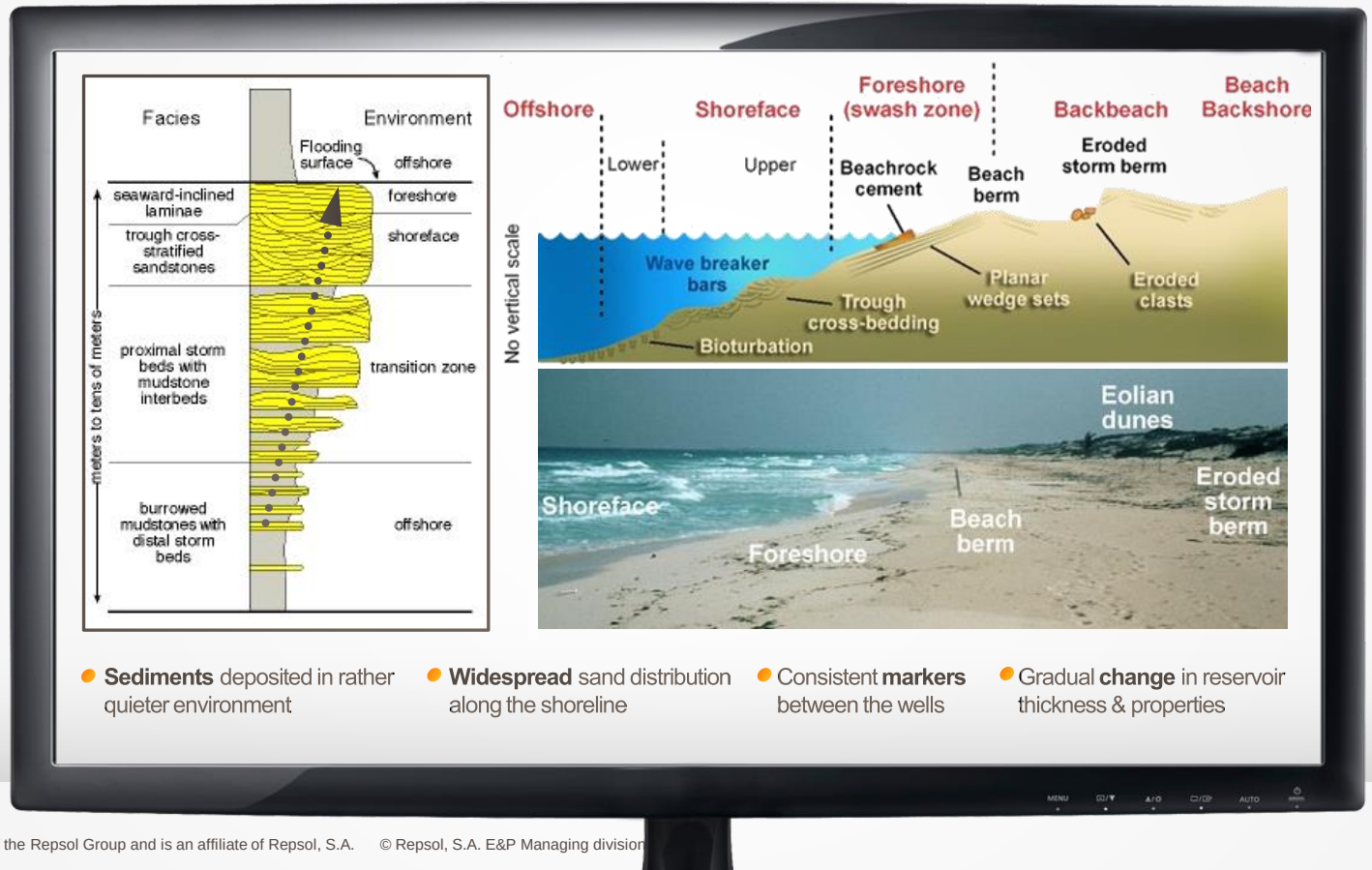
Structure:

- **Fields separated** into 3 fault blocks by NE-SW trending extensional faults
- **3 way** dip structural traps with no significant internal faulting
- **Significant growth** on Main fault (up to 4000ft throw in Hanging Wall)

Reservoirs:

- **Multiple stacked shoreface** sandstones of Miocene age
- **Over 6000 ft** total thickness in Main field
- **Hydrocarbons** occur as oil in Main field with some associated gas caps
- **Deeper reservoirs** (>12,500 ft) occur as NAG and are over-pressured
- **Average reservoir thickness** up to 180 ft and are laterally continuous
- **Extensive core collection,** total >1200 ft.

Depositional Model

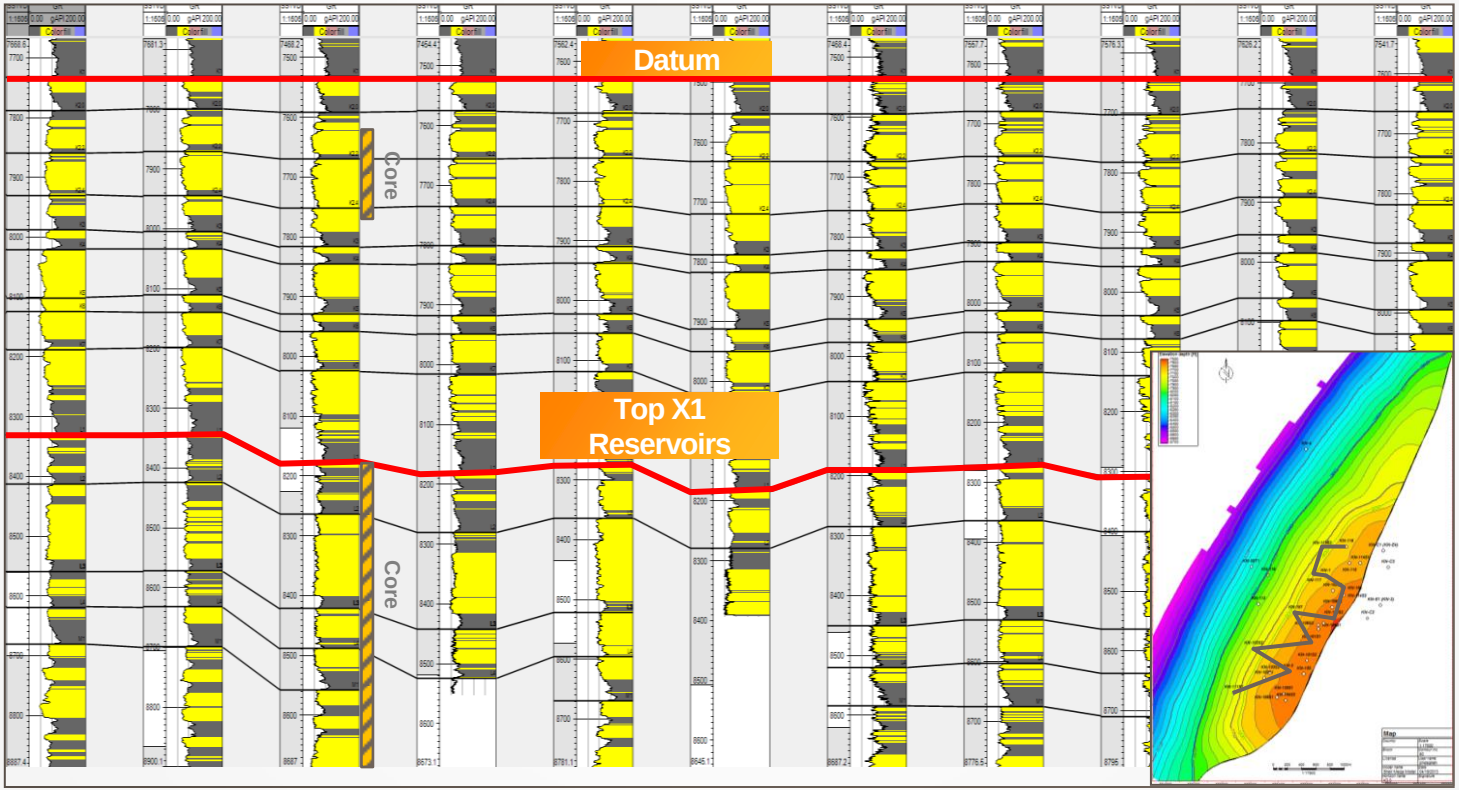


- **Sediments** deposited in rather quieter environment
- **Widespread** sand distribution along the shoreline
- Consistent **markers** between the wells
- Gradual **change** in reservoir thickness & properties

Stratigraphic Well Correlation

SW

NE



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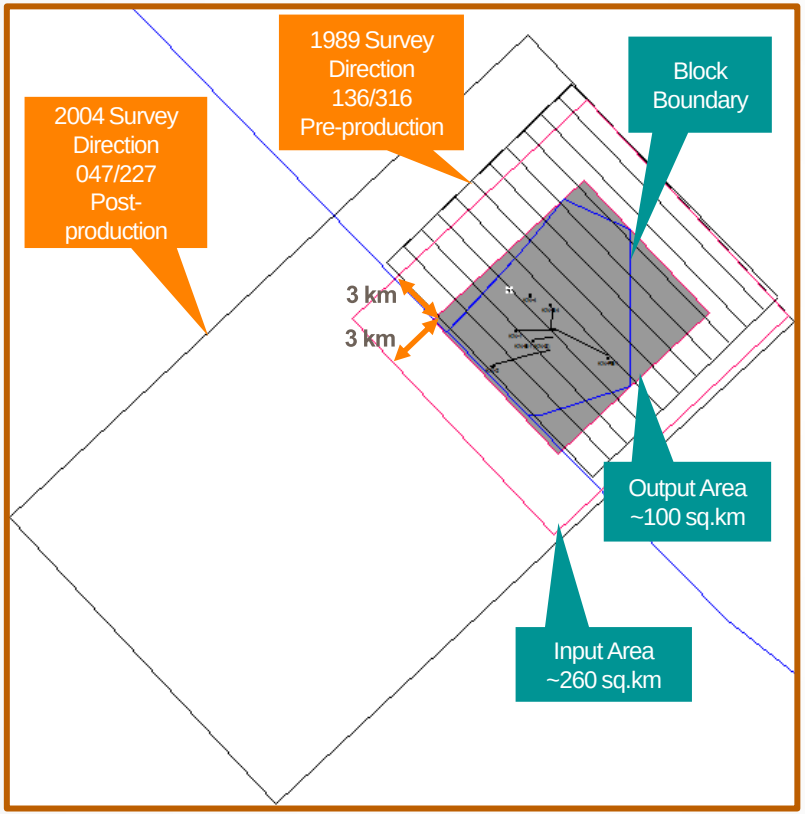
Multi-Azimuth 3D PSDM Processing



- **Objective:**
  Well-driven processing leading into a high frequency geostatistical seismic inversion facilitated for reservoir modelling workflows

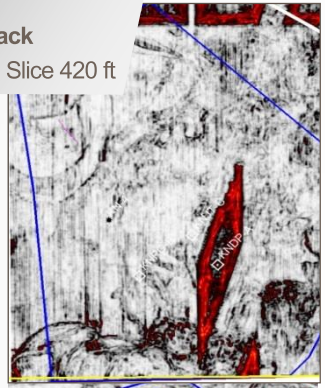
- **Main Interval of interest:**
  1000ms – 3500ms
  Main, B - S (Stochastic Inversion)
  East, X – Z (Stochastic Inversion)
  Far East, O – S (Stochastic Inversion)

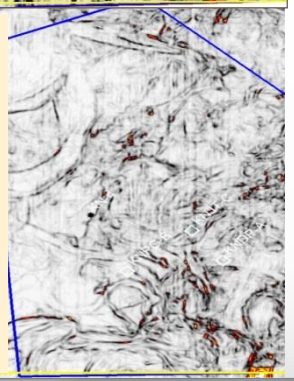
- **Input data:**
  1989 Survey (136 deg/3200m)
  2004 Survey (047 deg/6000m)
  6 wells with rock physics analysis

- **Output data:**
  CDP gathers
  Partial Angle Stack
  Full Stack
  MAZ Stack
  Impedance – Ip, Is
  Vp/Vs
  Lithofacies probability (Sand,Shale,Brine,Oil &Gas)

Improved Imaging

PSDM MAZ Stack
Variance Depth Slice 420 ft



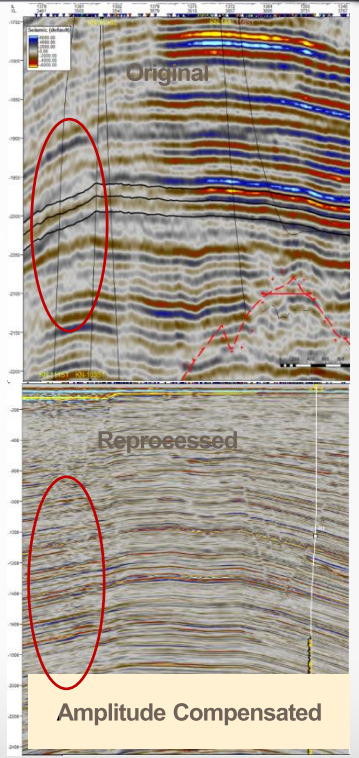


- Acquisition footprint removed
- Undershoot area filled
- Detailed geological features enhanced

Well calibrated, Amplitude preserved & Broadband processing using conventional streamer data

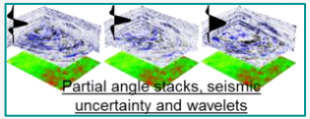
Key Processing Steps:

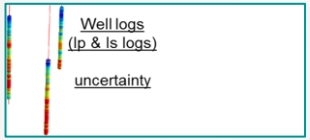
- Demultiple:
  - Shallow Water Demultiple (SWD)
  - Surface Related Multiple
  - Elimination (SRME)
  - Source Receiver Deghosting Radon Demultiple
- Acquisition footprint removal
- Pre Stack Depth Migration (Orthorhombic Anisotropic – HTI)
- Multi-Azimuth(MAZ) Stack

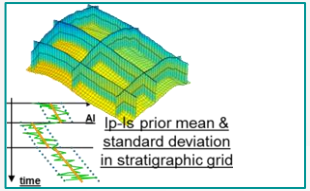


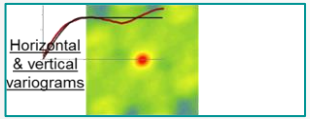
Stochastic Inversion

and Lithofacies Classification

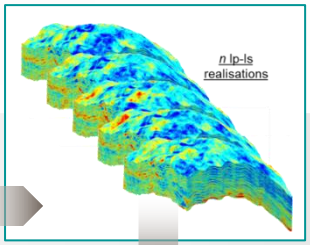


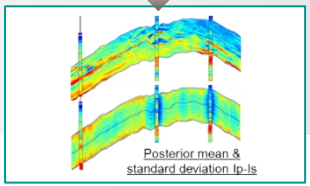




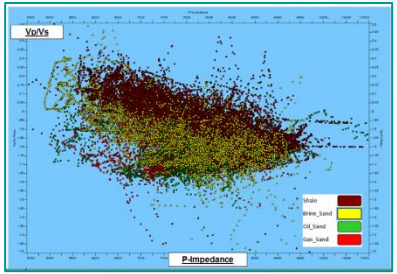


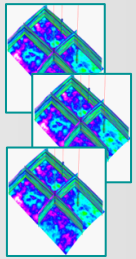
Combine to create a posterior distribution

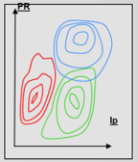


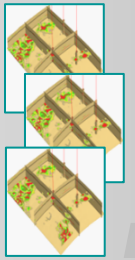


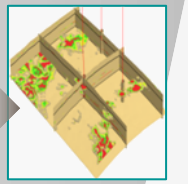
Lithofacies Classification









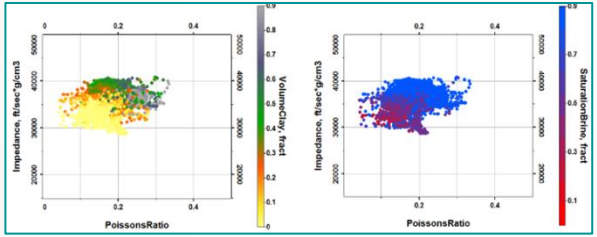


Average probability cube

n realisations of Ip, Is

n facies probability simulations

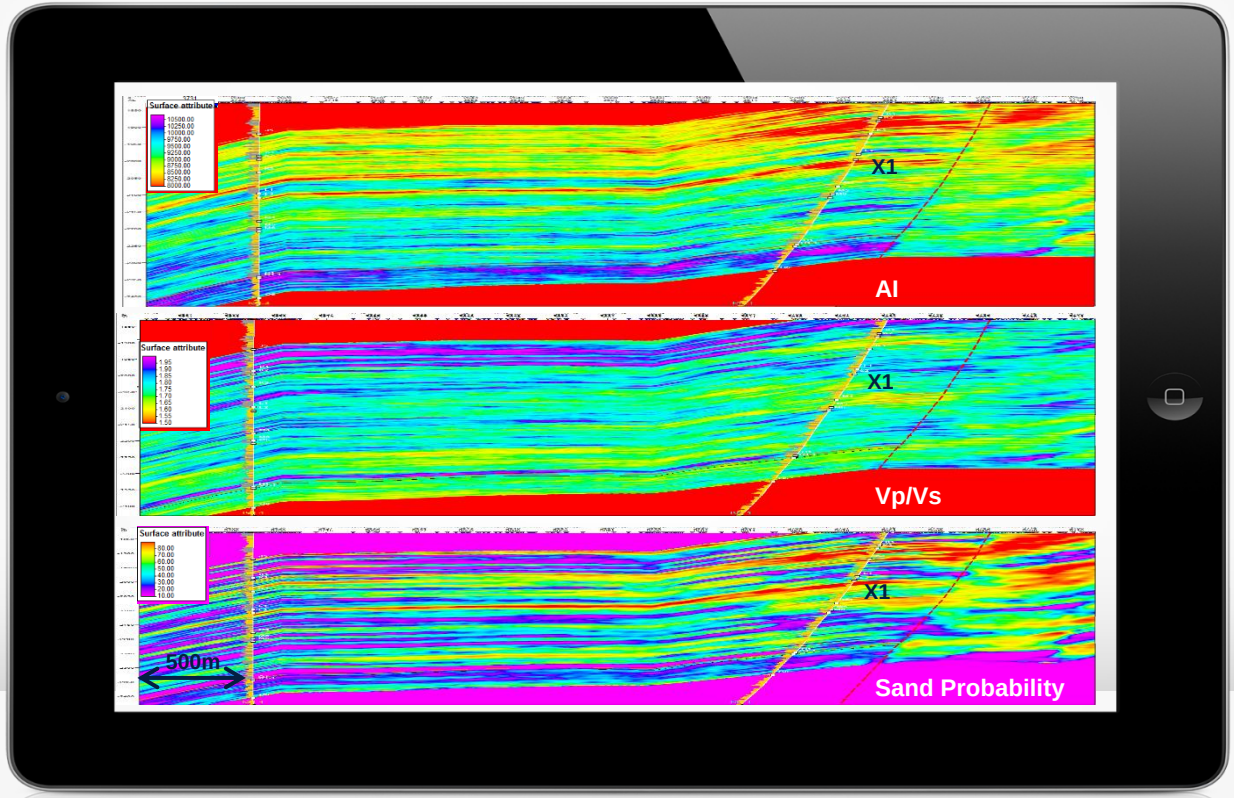
Rock physics Analysis



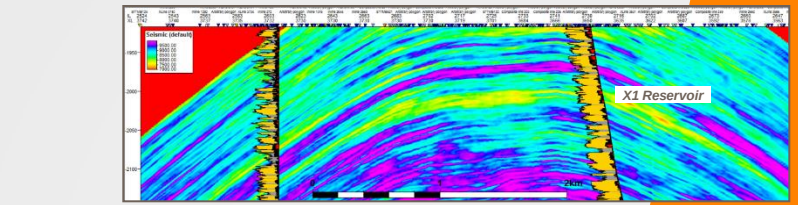
Geo SI – Litho SI

Cross-section of Composite Seismic

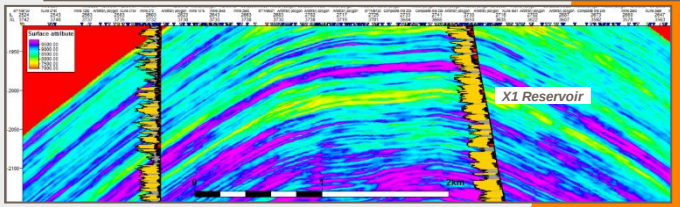
Inversion Attributes



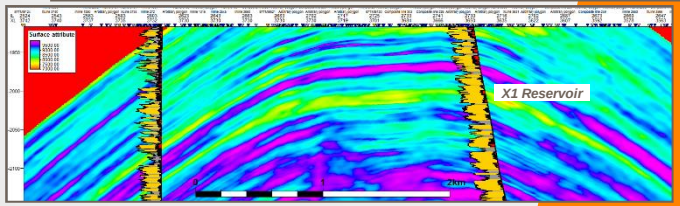
Cross-section of Composite Seismic Inversion (P Impedance)



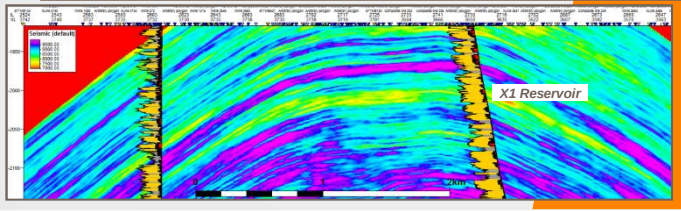
P90 (P Impedance)



P50 (P Impedance)



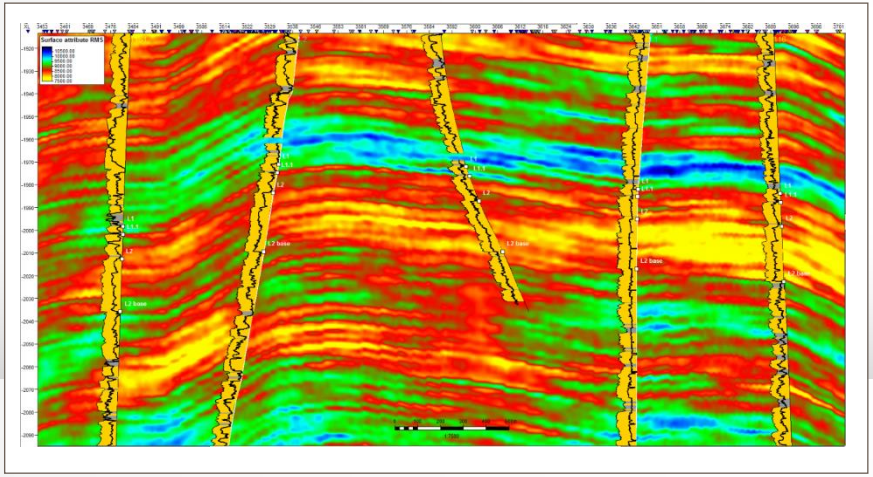
PMean (P Impedance)



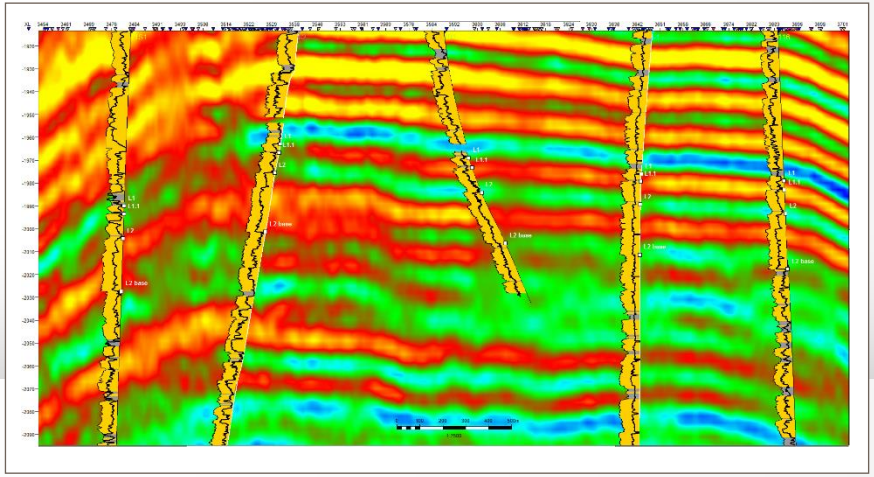
P10 (P Impedance)

Comparing Deterministic & Stochastic Inversion

Stochastic Inversion



Deterministic Inversion



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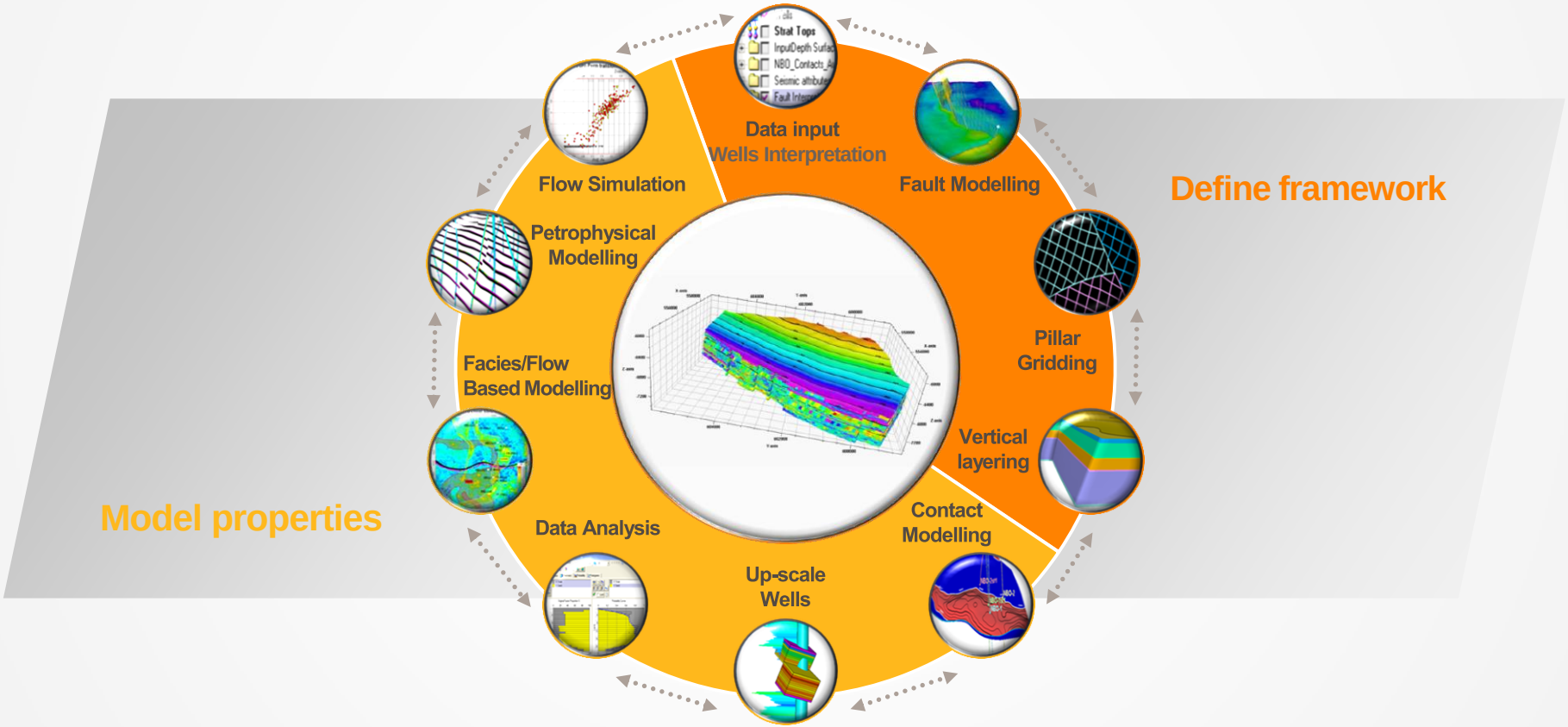
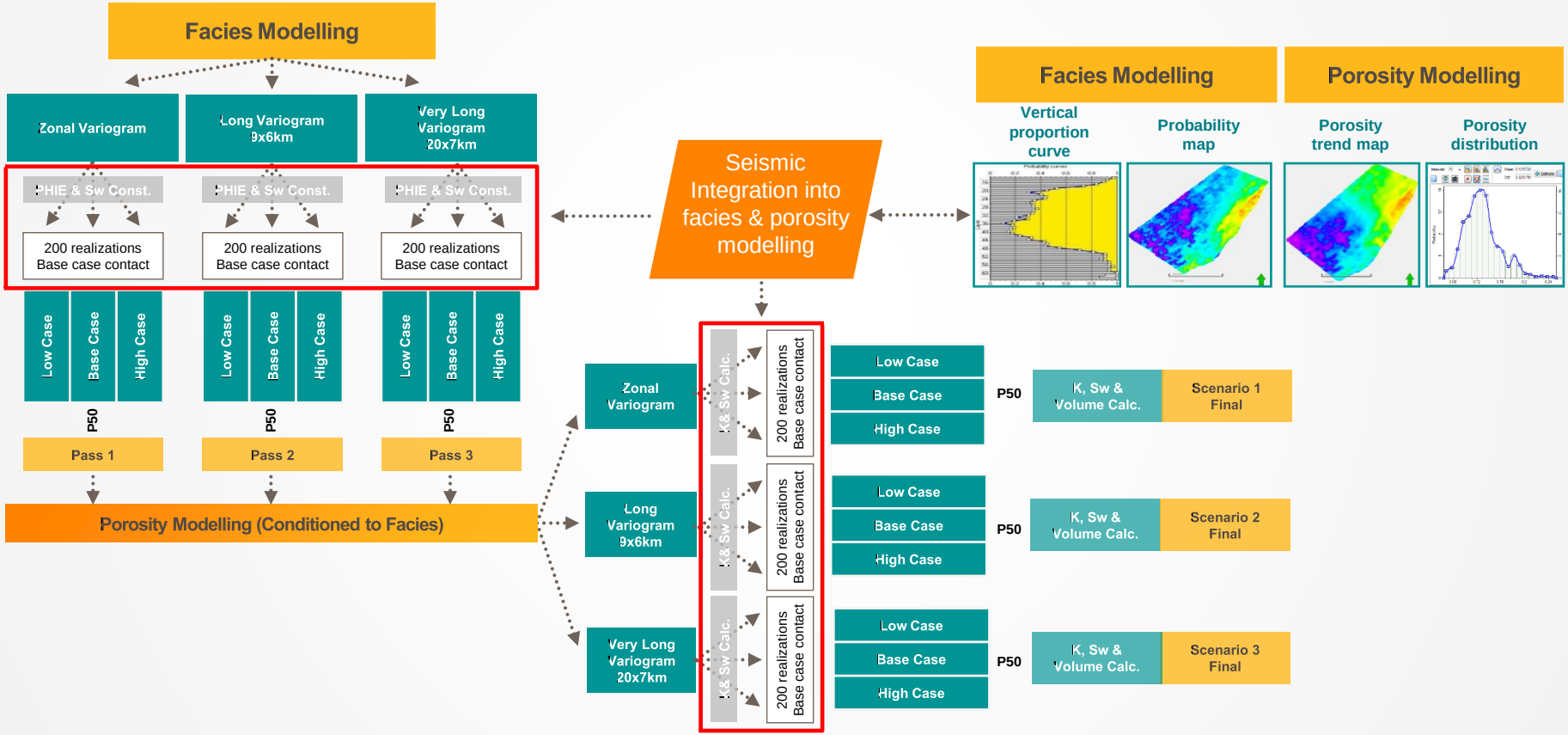
3D Static Modelling Workflow



Reservoir Property Modelling Workflow



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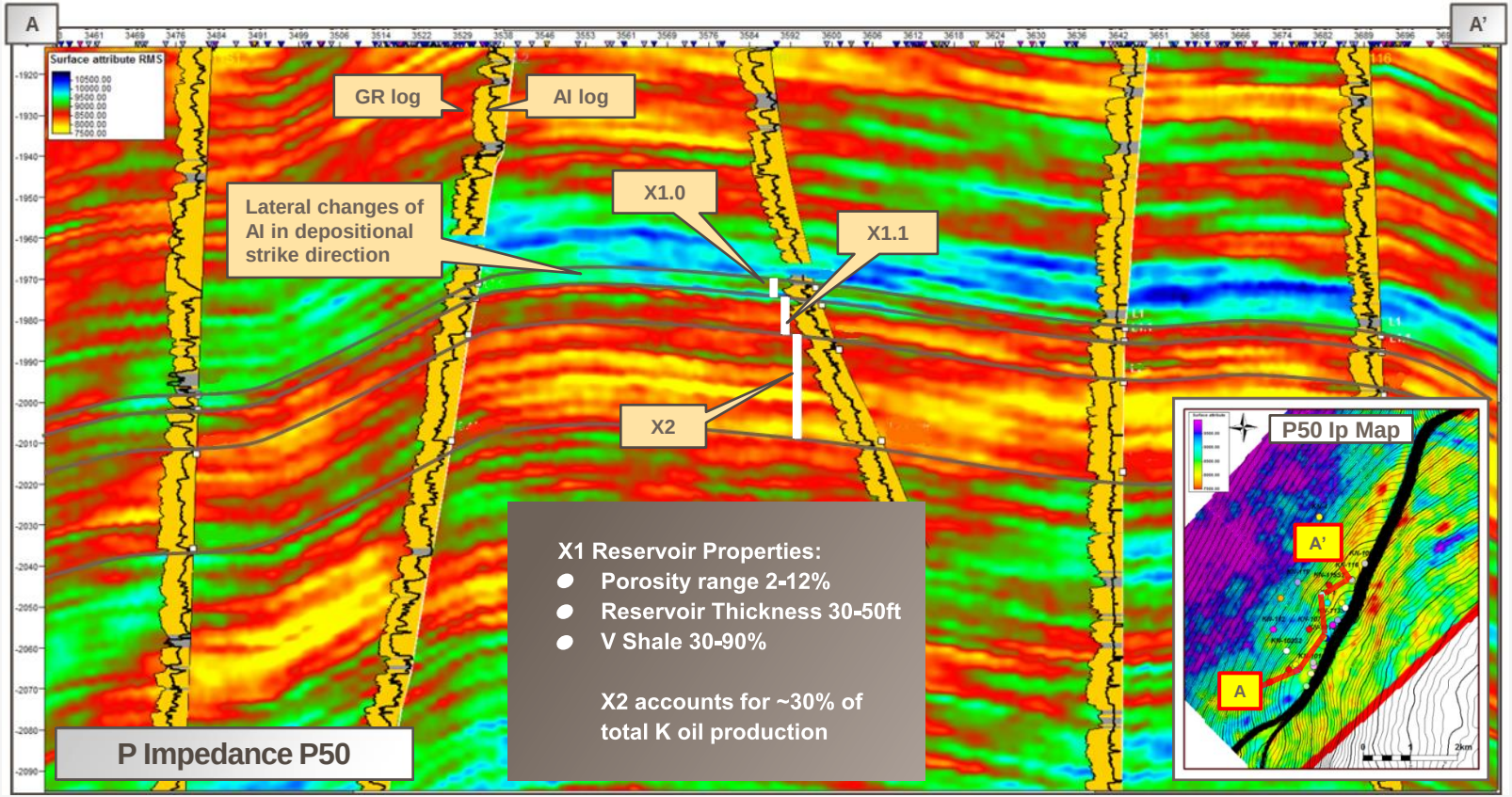
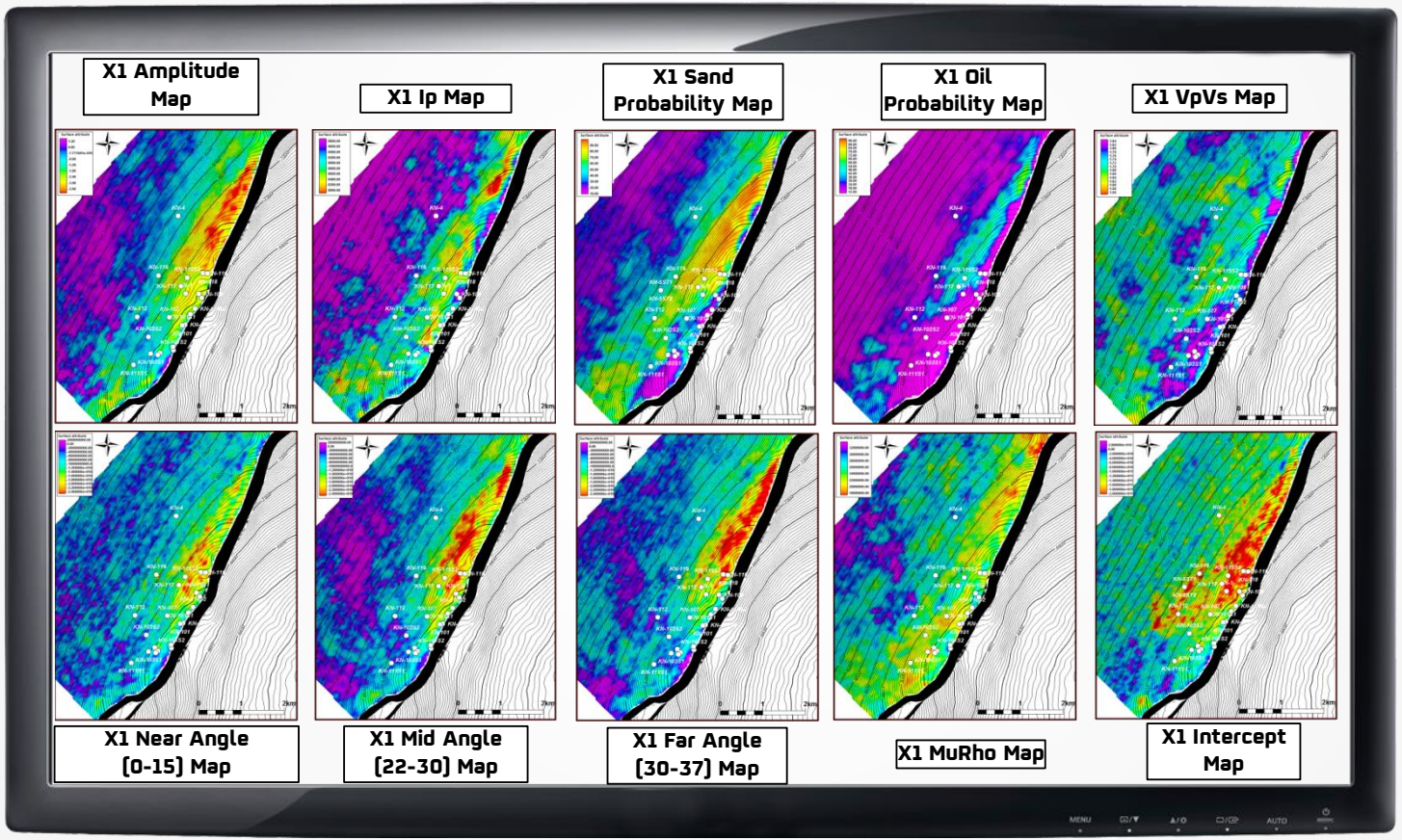
X1 Seismic Attributes Related to Reservoir Properties

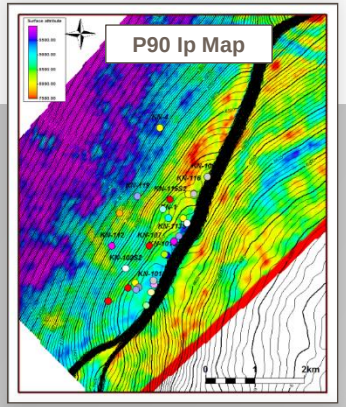


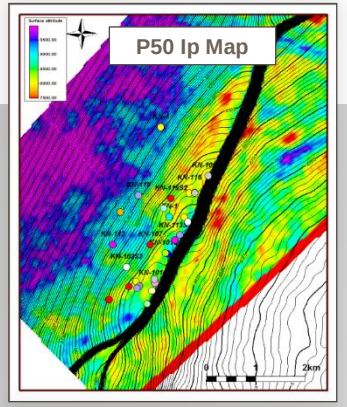
X1 Multi-Attribute Extractions

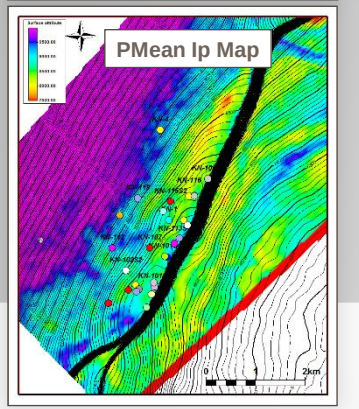


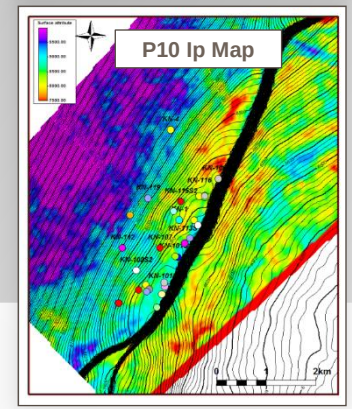
Acoustic Impedance (Ip) Maps

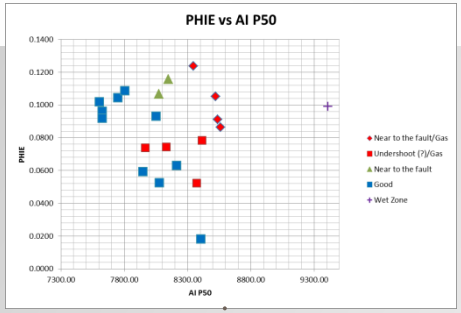
X1 Reservoir

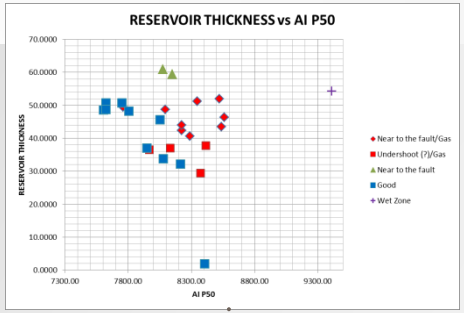


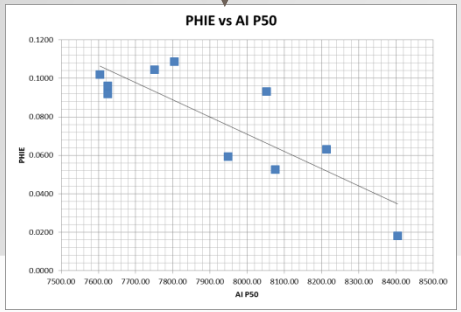


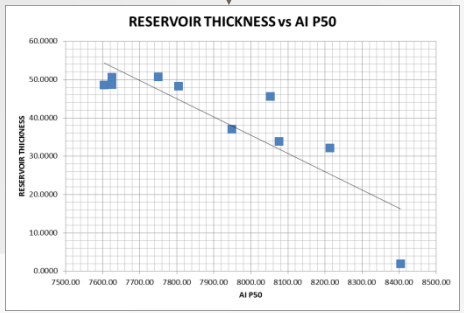






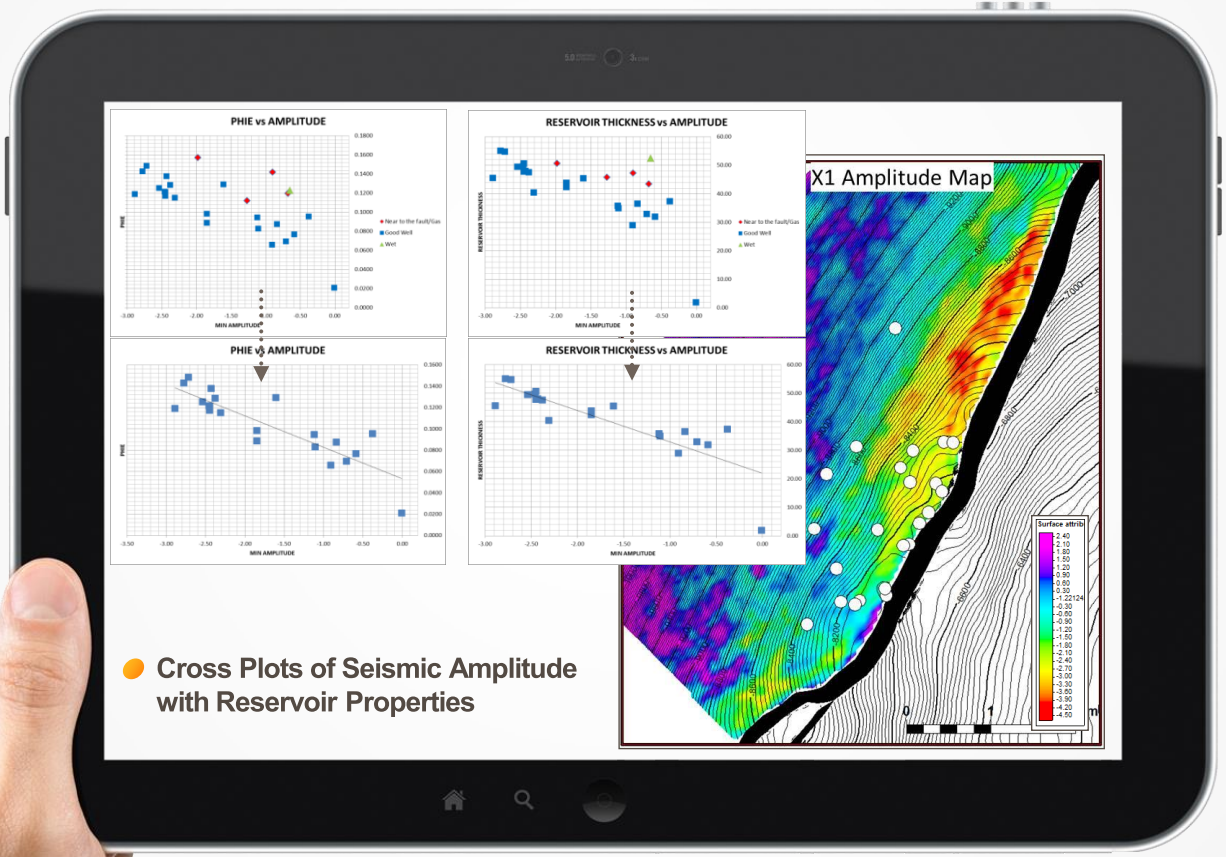




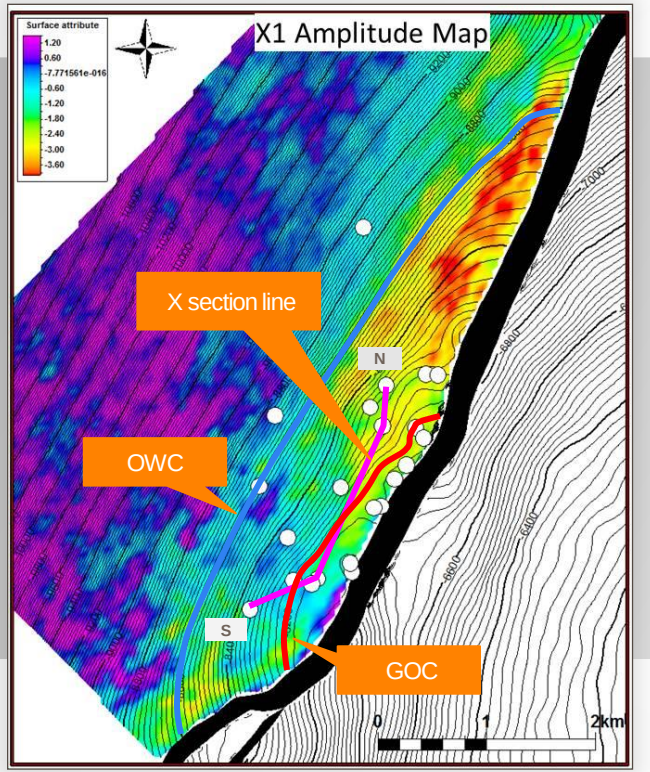


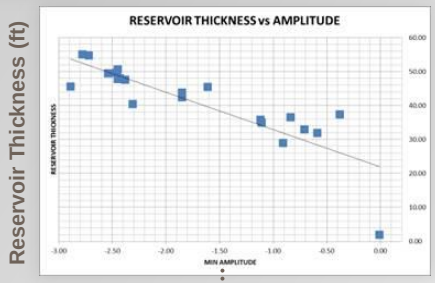
Observed Amplitude Anomaly

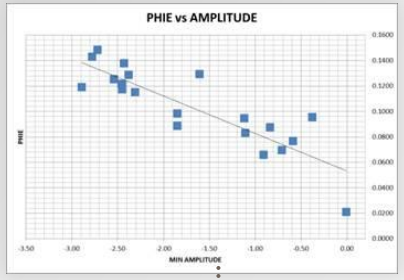
X1 Reservoir

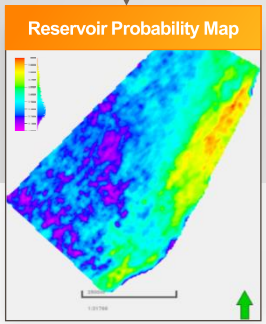


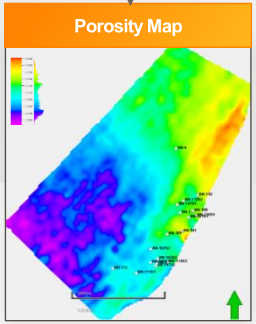
Geophysical Integration in 3D Static Modelling





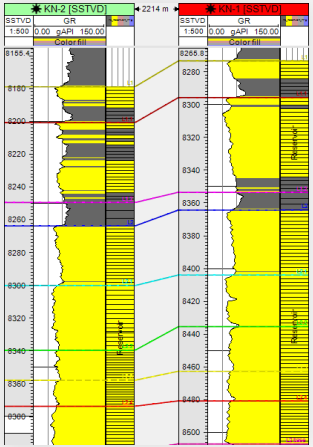






3D Facies Modelling Workflow

1 Upscale PS_RESERVOIR to grid scale



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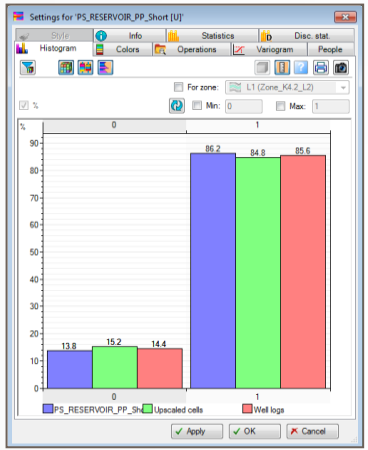
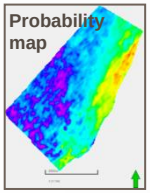
2 QC histogram between raw and upscaled logs



3 Running process

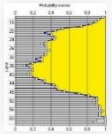


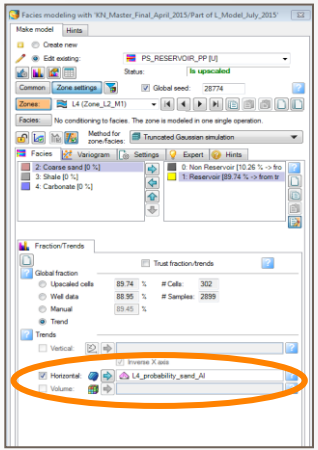
Run 200 equiprobable realizations using TGS.

Variogram

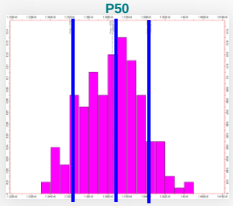
VAR
LVAR
VLVAR

Vertical Proportion

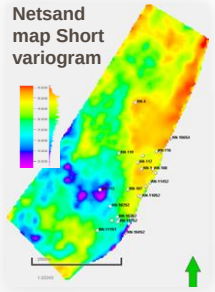


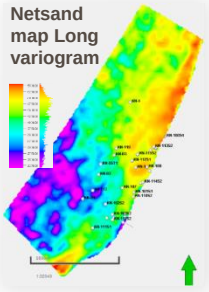


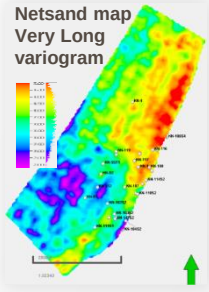
4 Zonal P50 select



Based on volumetric Zonal Histogram (P50)

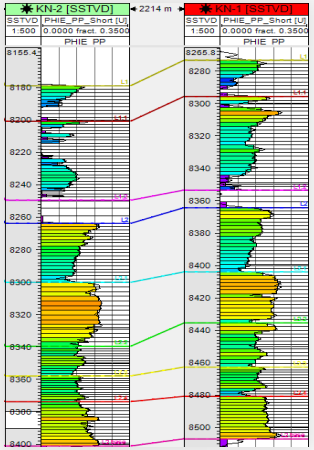






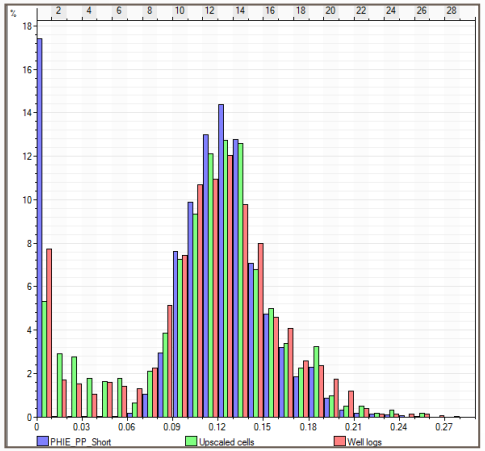
Porosity Modelling Workflow

1 Upscale PHIE to grid scale

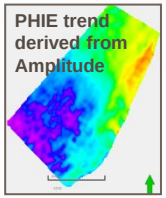


+

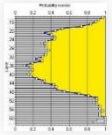
2 QC histogram between raw and upscaled logs

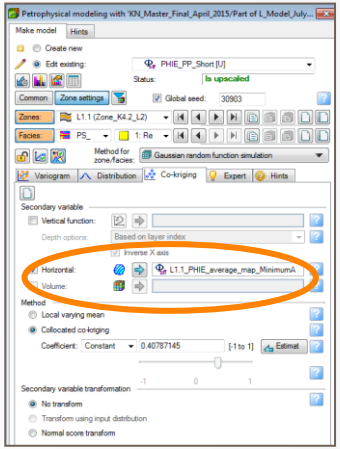


3 Running process

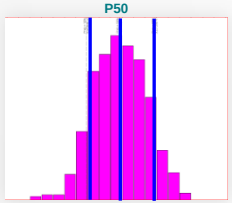


Run 200 equiprobable realizations using GRFS.

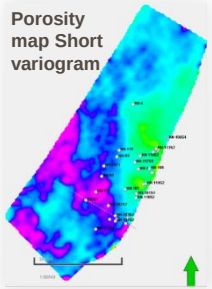
Variogram	Data Distribution
VAR LVAR VLVAR	

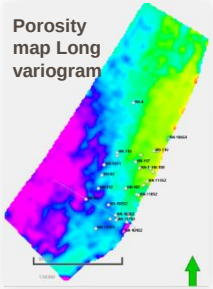


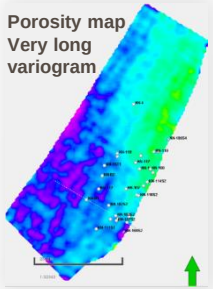
4 Zonal P50 select



Based on volumetric Zonal Histogram (P50)





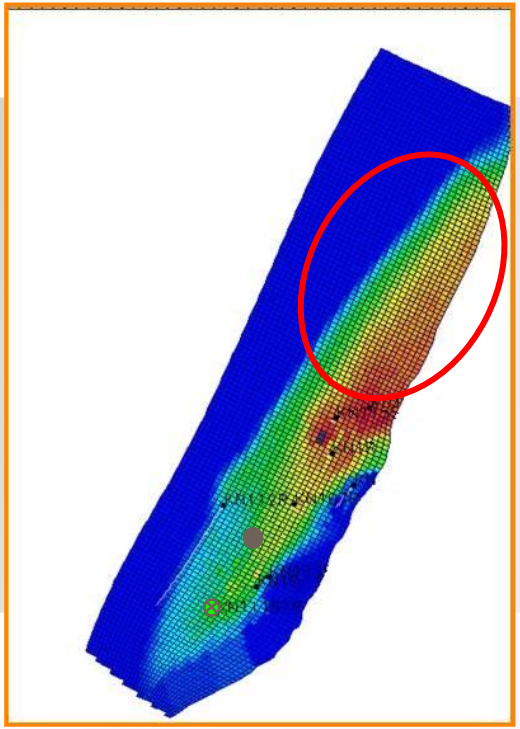


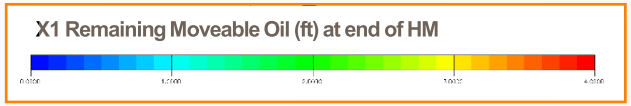
Dynamic Simulation Result

X1 Reservoir Potential

Moveable Oil (ft)

- P&A
- Shut-in
- Potential Further Development Area





K Field Overview

Geological Background

Geophysical Study

3D Static Modelling

Case Study – X1 Reservoir

Summary

Summary

1. **Integration** of the geological and geophysical data (reprocessed seismic and inversion) provides better reservoir characterisation in 3D Static Modelling

2. **Stochastic** inversion is able to separate individual sand bodies in a multi-stacked reservoirs

3. Seismic attributes have been used as a trend map to guide the reservoir **properties in 3D modelling** process and well placement optimisation

4. **X1 modelling** results suggest undrained potential in the northern part of the K field – a prospective target for an infill well

Acknowledgement

PETRONAS

REPSOL

Mr Kwong Wee, Poh (Co-Author)